SIMULATION ANALYSIS OF OUTPATIENT APPOINTMENT SCHEDULING OF MINNEAPOLIS VA DENTAL CLINIC

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This thesis describes the research carried out by the author with guidance and contribution from some collaborators. The author worked closely with her graduate adviser, Dr. Caroline C Hayes on the data analysis, simulation modeling and preparation of each chapter of this thesis.

The author received support from the medical staff and clinic management at the Minneapolis VA dental clinic. Lou provided additional information about the management structure, clinic layout and clinic. The data used for analysis and modeling has been collected by Shahrzad Grami along with Prof. Caroling Hayes by distributing induct cards to the patients at the Minneapolis VA dental clinic.

It is to be noted that all the data involving patient wait times used for the simulation has been collected by Shahrzad Grami and Prof. Caroline Hayes and all the analysis and simulation is the contribution of the author with guidance from Prof. Caroline Hayes.

DEDICATION

This thesis is dedicated to my parents for their love and support

ABSTRACT

Providing quality and timely care to patients has been a constant challenge to the healthcare industry. Long waiting hours and unavailability of timely appointments is a major source of dissatisfaction among patients. This thesis aims at studying the current scheduling practices and understanding the shortcomings of the Veterans' Affairs (VA) dental outpatient clinic in Minneapolis, MN. The clinic is confronted with both long waiting hours and unavailability of appointment slots for patients and extended working hours for the staff. The hospital management reported that the average wait time to get an appointment is approximately 60 days.

Time measurements, observations, and data mining in the clinic's management information system show the performance of the outpatient clinic in the current scenario. After analyzing the data, simulation models of the dental clinic were created based on the parameters obtained from the collected data. Based on the pitfalls and performance metrics of the current scheduling system, three appointment configurations have been suggested. The appointment schedules have been modeled and compared with the current system. The model evaluated the performances of the clinic using theoretical probability distribution for patient arrivals and consultation times as input parameters.

Current scheduling system has four appointment types with 30, 60, 90 and 120 minute durations. Modifications were suggested to the present model based on logical reasoning and statistical data obtained from the simulation model. The model was simulated with fewer number of appointment types to reduce the complexity of the system and see the effect on the resource utilization and wait times in the clinic. In the second scenario, appointments were given with a pool of resources rather than individual resources, in an attempt to reduce the wait times.

The simulation results suggested that desirable effects on the resource utilization can be brought about by employing minor changes to the present system. A new method for allocating hygienists has been suggested which reduces the wait times by more than seventy percent. As a result of the reduced wait times; more patients can be treated by the clinic on a daily basis, which would reduce the access delays significantly.

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Chapter 1
Introduction

The aim of this thesis is to understand the scheduling challenge faced by the Veterans' Affairs dental clinic at Minneapolis and suggests improvements. This thesis restricts its scope to the appointments managed by the outpatient dental clinic.

With privatization and technological advancements in medical treatments, their service levels majorly determine the quality of healthcare provided by the health practitioners. Delivering timely and efficient care is one of the important criterions for patient satisfaction and is also necessary for good medical outcomes. Appointment scheduling lies at the intersection of timely access and efficiency of the delivery systems [1].

While the VA dental clinic in Minneapolis is improving actively in providing state of the art health services, the inability to adapt and make use of the technological advances for a better delivery system and resource management leaves room for improvement. An apt example demonstrating the inefficient usages of the technology are the computer based scheduling system. Although a number of excellent scheduling software programs are available in the market, human schedulers are reluctant to make use of the available technology and often resort to traditional methods. In such a scenario, data entry tasks are often seen as a burden, which could have been avoided by the use of software in the first place. Hence, a technological advance that is designed to make work easier often fails to serve the purpose.

The inefficiencies of a system become more significant with the increase in number of patients seen at the hospital. Need for more staff, care providers, equipment, and resources needs additional funds for the hospital, which is a rarity now. A few of the major challenges faced by the VA dental clinic are difficulties in access to healthcare, managing patient and staff scheduling, long waiting times for appointments and treatment, congestion of space, demand for additional resources and so on.

Waiting times are major source of dissatisfaction among patients and are mainly result from inefficiencies in the existing processes and practices, or when the patient needs exceed the capacity of the clinic. Clearly, all the problems faced by the clinic can be attributed to the lack of a competent scheduling system. Delays can happen at various junctures, from the scheduling of appointment to various stages during the treatment process. Figure 1 gives a generic process flow of patients across the hospital facility. In the current scenario, the delay in scheduling an appointment from the time patient requests an appointment is often close to 60 days at the VA clinic. Some of the main reasons for the delayed treatments are poor coordination of information among the clinic staff for scheduling appointments, inefficient usage of resources, poor scheduling algorithms that fail to address the variability of patient demand, inaccurate time estimations of appointments, and patient and care provider timeliness in maintaining the appointments. Along these lines, the main objectives of this thesis are *to study the appointment scheduling at the VA dental clinic, to identify the causes of direct and indirect delay in appointments and to maximize the productivity of the system.*

The main challenge of this study lies in understanding the causes of delays at various stages across the clinic and taking remedial actions. The problems are complicated due to dependency on a number of parameters like patient and care provider punctuality, variations in consultation times, availability of resources, and uncertainty in walk-in appointments (emergencies) and so on. In such a scenario, it's tough to isolate the problem to take corrective measures as changing one parameter might affect another, which could result in aggravating the problem.

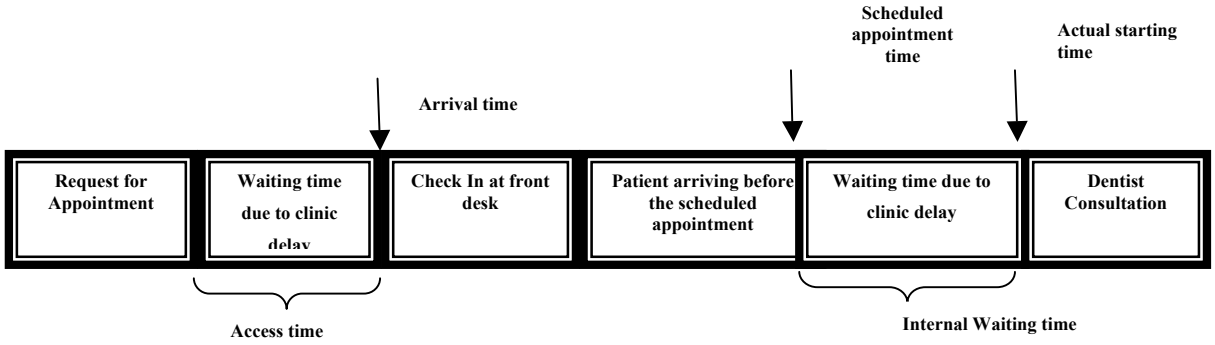

Figure 1: Patient flow through the outpatient clinic

To understand the shortcomings of the current scheduling system, data has been collected from first hand observations and measurements. Physicians and hospital staff were shadowed throughout their daily activities to understand the scheduling and treatment process. This information has been supplemented with interviews and meetings with hospital management and analysis of monthly metrics obtained from hospital records. Simulation and queuing models have been designed based on the data collected to examine patient waiting times and bottlenecks. The models created captured the flow of individual patients through different care pathways in the clinic while incorporating the factors of variability and uncertainty in patient demands. The models were tested against the current clinic settings and various performance parameters like waiting time of patients, number of patients seen, room and physician utilization have been measured.

The simulations suggested that the appointment types play a pivotal role in affecting the resource utilization of the clinic. In addition to this, it was also found that the clinic is not being run to its maximum capacity, which leaves scope for improvement. The effect of pooling the resources together, in the utilization of the clinic was also studied and the outcome showed drastic reduction in waiting times leading to higher resource utilization.

The modifications as suggested to the current system can bring substantial increase in the resource utilization as shown by the simulation results. The suggestions can be implemented easily without involving major overhaul of the clinic utilities. Improved resource utilization would imply better use of the resources resulting in satisfied customers. Though the simulations and the study are specific to the VA clinic, the current scenario is same for most other healthcare providers. Hence, this study can serve as a starting point to improve the resource utilization of these clinics.

The thesis is organized as follows.

Chapter 2 (Literature Review) summarizes different work published in the field of appointment scheduling in healthcare. Important parameters necessary for designing an appointment system and existing scheduling practices are discussed in length.

Chapter 3 (Veterans Health Administration) describes the appointment scheduling at VA dental clinic, Minneapolis. The processes and patient flow across the system is detailed. The current appointment system is analyzed based on various performance metrics. Model of the outpatient dental clinic is built based on the data collected at the VA clinic to evaluate the appointment system.

Chapter 4 (Research Overview) discusses in detail the research methodology followed during the course of this study.

Chapter 5 (Simulation) details the different parameters used in the simulation model and explains the decision on the input and control parameters included for evaluation of appointment system. The data collected at the clinic was analyzed and probability distributions fitting the system behavior are identified.

Chapter 6 (Results and Discussion) presents the results. Three alternative systems are compared to the existing system and performances are compared.

Chapter 7 (Conclusion and Future work) lists the recommendations made to the clinic based on the analysis of alternative design systems discussed in previous chapters.

Chapter 2

Literature review

The healthcare industry represents one fifth of the US economy and has a great social significance. The total healthcare expenditure in the US for the year 2009 was reported to be $2.5 trillion and is expected to increase in the coming years [1-5]. The rising costs can be attributed to the growing and ageing population, research and development costs, infrastructure improvements and inefficiencies of the existing systems in delivering timely and accessible care. Service providers are under constant pressure to deliver quality services.

Appointment scheduling is one of the most challenging systems to be designed in service industry and healthcare is no exception. The appointment system was put in practice for the first time in 1952 based on Bailey's appointment rules, prior to which patients were treated on first come first serve basis [8]. The scheduling system has evolved over times from block scheduling to individual appointment system to same-day appointment accessibility to cater to the needs of growing patient demands. The increase in population, advances in medicine and ease of accessibility to medical resources have further complicated the scheduling process [1].

With the increasing costs of healthcare, providers are challenged to increase the efficiency and productivity of the clinic with the existing resources. The aim of a general appointment system is to balance patients' waiting time, doctors' idle time, and doctor's overtime [32]. Long waiting hours and unavailability of timely appointments is a major source of dissatisfaction among patients. In emergency cases, patients are stressed waiting to be treated and experience a lot of anxiety in addition to the physical pain. Crowding near facilities, long queues, extended work hours and inefficient usage of resources can decrease the overall productivity of the system and is concern for providers []. Hence, for providing timely and efficient care, patient scheduling should be well designed and executed. Regulated patient flow would avoid delays and reduce waiting

time improving the entire treatment process for the patients and service providers. A well-designed patient schedule is also necessary for efficient utilization of resources.

2.1 Patient Scheduling

One of the main objectives of the appointment scheduling is to balance the interests of both care providers and patients. Patients prefer shorter waiting times and quick access to the clinics while care providers prefer less idle times and getting the work done on time. The pressing need for better patient scheduling system has triggered many investigations in the topic of appointment scheduling.

Bailey and Welch were the first to introduce the scheduling rules in 1952 and tested it through simulation [11]. Since then many studies have been undertaken analyzing appointment systems in various settings [1, 6-15]. An extensive review of the literature on outpatient appointment systems can be found in Cayirli and Veral [8]. Most of them use simulation to analyze the performance of different appointment scheduling rules. Various appointment systems are being practiced across the healthcare industry, a few of which are discussed below.

1. **Block scheduling**

The most primitive form of outpatient scheduling is single block scheduling, where patients are assigned a "date-only," rather than a specific appointment slot [8]. The single block rule assigns all patients to arrive at the same time. For instance, all patients are scheduled for one appointment time – 9:00 am to 2:00 pm. Patients are served on first-come, first-serve basis. This system increases the care provider utilization but affects the patient waiting times [8,11]. Patients at the end of the queue or the schedule block tend to experience longer delays than the patients at the start of the block. The care providers and staff work might also have to work under the constant stress of the fear of backlogs in case of any extending appointments. This was the most common practice in most of the clinics in 1950's and is still used in public clinics as it requires least administrative efforts [10].

2. Individual appointment scheduling

Individual block rule is the most common form of scheduling. Bailey was one of the first to analyze an individual block system. The individual-block/fixed-interval system, gives unique appointment times with fixed durations to patients spaced over the clinic session [8].

Individual-block/fixed interval with an initial block system is an extension to the above rule where Bailey combined single block and individual block scheduling rules and assigns two patients at the beginning of the session while the rest of the appointments are scheduled at intervals equal to the mean consultation time [3, 8, 9, 11]. The idea behind scheduling multiple patients at the beginning of the block is to minimize the doctor's risk of becoming idle if one of the patients fails to show up on time. All other patients are assigned unique appointment times spread throughout the clinical session. Bailey also found that shorter mean consultation times result in lower patient waiting times. Furthermore, he found that high variability of service times deteriorates both the patients' waiting times and the doctor's idle time.

When two or more patients are scheduled for the same appointment, the scheduling is referred to as double booking. This kind of scheduling is good when the patient visits are brief. In cases where hour long consultations are required, double booking might not be the best idea. If the consultation time of both the patients is not managed within the appointment slot, the delay might affect the patient appointments scheduled for latter part of the day. Patients can also get annoyed if they realize multiple appointments are scheduled for the same hour. Also for patients who do not understand the complex set up of this appointment system might mistake this practice as a compromise of the quality of care provided.

Individual-block/Variable-interval rule is one in which customers are scheduled individually with varying appointment intervals. The appointment durations are based on the mean consultation times of the treatment procedures. Variable appointment types can be implemented in this system fitting the demands of patients with different medical

issues. Ho and Lau introduce a number of variable-interval rules and test their performance against traditional ones using simulation [6, 8]. The results showed that the best performing variable-interval rule increases appointment intervals toward the latter part of the session.

Klassen and Rohleder classify patients based on their expected service time variability [22]. . They developed a rule that puts patients with lower service time variability before patients with higher service time variability, which performs better than Ho and Lau's best performing rules. Grouping similar appointments and scheduling them together during the day or week is also known as clustering. This method is helpful when special equipment or tools are necessary for the treatment. The advantage of this practice is the time conserved in setting up and prepping for treatments. Also, in cases where resources are minimal, maximum utilization of resources happen in these cases.

The Minneapolis dental clinic follows an individual block variable interval rule scheduling policy. The clinic schedules appointments with 30, 60, 90 and 120 minute duration. The shorter consultations are scheduled in the beginning of the day while the longer consultations are placed towards the later part of the day.

3. Open access scheduling

Open access system schedules patients on the same day the patient requests for an appointment, irrespective of the severity of the medical condition. This is the latest kind of appointment system in use and is actively being adopted by hospitals and clinics all around [11-19]. This scheduling allows patients to consult care providers as and when necessary rather than a future appointment as is the case with the traditional system.

This kind of scheduling should not be confused with walk-in appointments. Emergency or walk-in cases do not call in advance for appointments. However, this system accommodates both the emergency walk-ins as well as the scheduled appointments. Provider schedules are left open with minimal pre-bookings to allow adequate capacity to meet demand for appointments. This system eliminates the triage system as appointment times are available for all types of patient visits [13].

This system increases the efficiency of the clinic and improves the overall productivity. Instead of forecasting care providers schedule for a future day, this appointment system plans for the given day. Hence the probability of making mistakes with the care providers schedule is limited. Another benefit of this model is the decrease in patient no-shows and cancellations. As the appointments are given immediately, the chances of cancellations/no-shows are considerably lower. The access time for appointments and internal waiting time is also drastically reduced. This system promises better healthcare and higher patient satisfaction.

The drawbacks of this system are the oversaturation of care providers' schedules. Open access scheduling can improve the patient access to physicians and reduce the uncertainty in clinic operations when the demand and capacity are properly balanced and estimated. However, when demand and capacity are not properly balanced, this system might lead to an increasing and unstable call rate, unfair access, and high patient dissatisfaction [21]. It is very tough to estimate the patient demand on daily basis and hence balance the patient care provider ratio. Also, open access scheduling might not fit all the medical specialties and will fail if not customized for the individual clinic's capacity and environment.

Often providers follow more than one of the above mentioned scheduling types to suit the demand and variability of the patients.

2.2 Model parameters

In this section the input parameters used for modeling the outpatient clinic and the appointment suggestions based on previous studies are discussed.

a. Patient arrivals

The arrival of the patients includes parameters like patient punctuality, appointment cancellations and no-shows and the number of walk-ins or emergency cases which is not controlled by the clinic. All these affect the patient wait times, idle time and overtime of both patients and doctors []. Only a few studies include punctuality, no-show

rates and walk-ins in their analyses. No studies are found that include appointment cancellations.

The no-show rate of patients is included as a fixed value in the majority of studies, and varies from zero to 20 percent []. In another study, no-show has been modeled stochastically from a uniform distribution [28].

The emergency walk-ins are limited and unpredictable. One common practice is to allow free slots to be filled only by emergency arrivals [22].

b. Patient classification

Patients differ in terms of service time characteristics, diagnosis, and urgency. If patients are grouped on basis of service time characteristics, the scheduler can adjust the sequencing and/or the appointment interval accordingly. Patients can also be classified based on their visit to the clinic as new or return. The service times and the check in times differ between the new and follow-up patients. It is also possible to group patients on basis of diagnosis and use this classification while assigning patients to doctors. Doctors may be able to treat only one or more types of diagnoses.

c. Service distributions

The service time of a consultation with a care provider is represented using continuous probability distributions, but a variety of distributions are used widely. Some of the distributions found in the literature are Gamma [11, 23], lognormal [22, 24], Weibull [25], uniform [28] and (negative) exponential [25, 26]. Some of them are fitted to empirical data [8, 27,28].

d. Care provider allotment

One of the common characteristics of almost all the studies on outpatient scheduling is the limitation of the model to a single care provider with one queue. Exceptions are Fetter and Thompson (1966), who schedule patients for three doctors, and the simulation model of Liu and Liu (1998), which includes two to five doctors. In both

the cases, patients are scheduled in one queue and are assigned to the first doctor available when they arrive.

Chapter 3
Veterans Health Administration

The United States Department of Veteran Affairs (VA) is a government run military veteran benefit system. It is the second largest federal department, after the Department of Defense, responsible for administering programs of veterans' benefits which include pensions, dependent and survivor benefits, disability compensation, life insurance and so on[46,47]. Based on the type of service, VA is subdivided into Veterans Health Administration (VHA), Veterans Benefits Administration and National Cemetery Administration [46].

Out of the three subdivisions, VHA is responsible for providing health care to the veterans. VHA has a huge network of 150 hospitals, 130 nursing homes, 950 outpatient clinics, and 230 readjustment counseling centers and vet centers spread across 21 regional health care networks called Veterans Integrated Service Networks (VISN). The VA Midwest health care network (VISN-23) serves more than 400,000 enrolled Veterans residing in the states of Iowa, Minnesota, Nebraska, North Dakota, South Dakota and portions of Illinois, Kansas, Missouri, Wisconsin and Wyoming [45].

VHA facilities provide a broad spectrum of medical, surgical, cognitive, psychiatric and rehabilitative care. The various services provided by the VA include primary, secondary, tertiary care and long-term care in areas of medicine, surgery, psychiatry, physical medicine and rehabilitation, neurology, oncology, dentistry, geriatrics and extended care. In addition, the extended care center provides hospice and respite care. The veteran's administration dental service is an extensive public program that includes service, education, training and research. On an average, VA handles more than 1.2 million dental treatment appointments each year in all its facilities [33]. Annually, approximately 1,200 students and residents are involved in education and training programs at this facility for medical, surgical, psychiatric, oral surgery, general dentistry, and diagnostic specialties

On the basis of recommendation of the VISN -23 management, the Minneapolis VA Dental clinic was chosen for the purpose of the study.

3.1 VA Dental Clinic

The Minneapolis VA Dental clinic provides quality dental care while simultaneously serving as a teaching institution. The VA dental clinic is an outpatient clinic providing dental services in a wide variety of areas: oral surgery, orthodontics, prosthodontics, periodontics and geriatric dentistry, oral pathology, endodontics, pedodontics, dental hygiene, sleep dentistry and public health.

The layout of the outpatient dental clinic is shown in figure 2. There are 18 dentist chairs in the VA clinic, out of which four are used exclusively for oral surgery and three are used for dental hygiene. The clinic employs 18 dentists specializing in various fields of dentistry. There are 6 full time dentists, 5 part-time dentists (working one day a week, each specialized in one area of dentistry), 2 general residents in clinic rotation and 5 full time residents who work along with dentists towards their medical training. There are 3 hygienists who specialize exclusively in dental hygiene. The clinic's support personnel include sixteen dental assistants, two dental laboratory technicians, and two medical administrative support staff (MSA). Receptionists handle the patient scheduling and check-in and check-out process. In general, practitioners only treat conditions in their field of expertise. There is a policy that patients receiving a particular treatment should be seen by the same care provider for the follow-ups or until they are referred to another care provider.

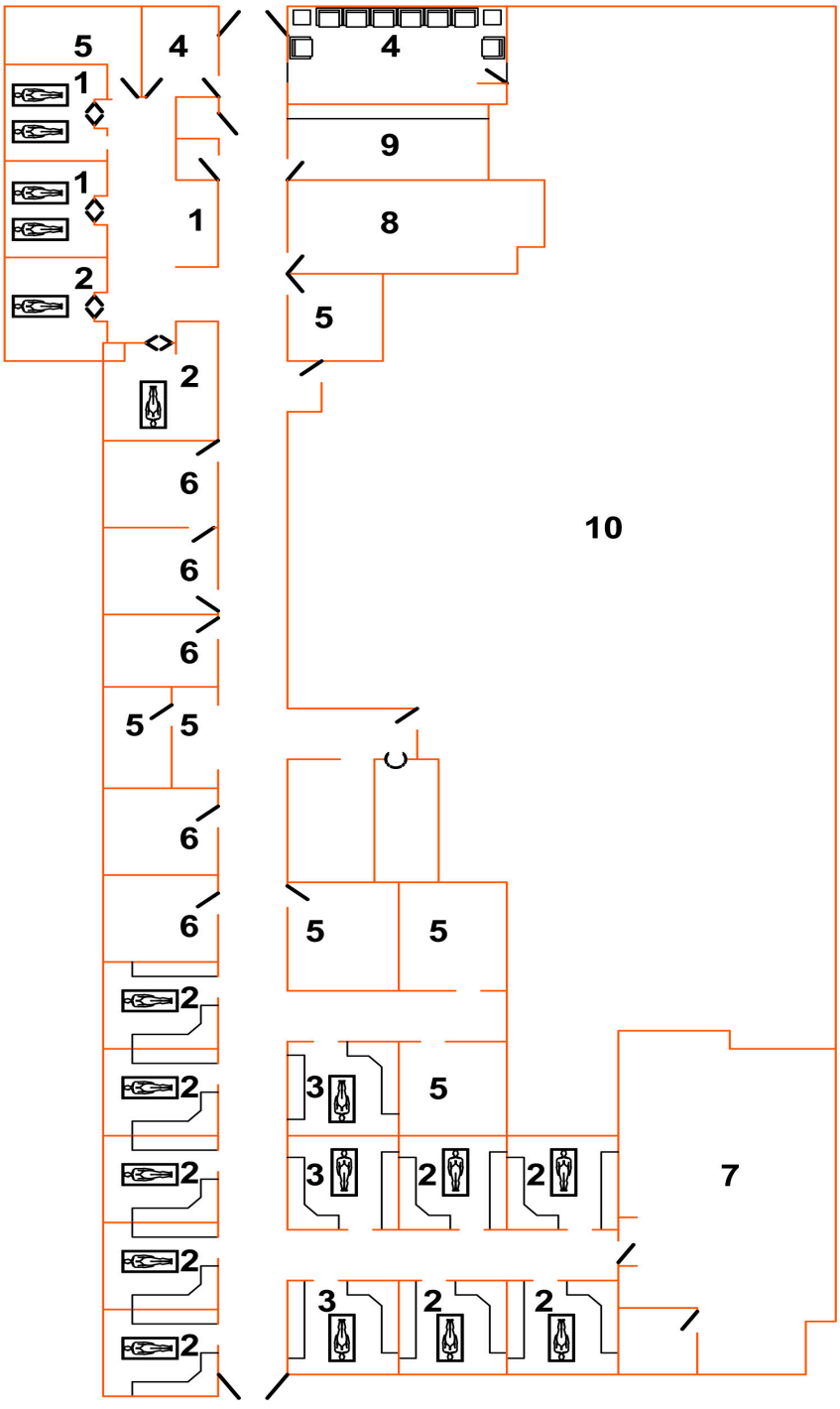

Figure 2: Schematic of the layout of the Minneapolis VA Dental clinic redrawn (the numbering represents 1-Oral Dentistry; 2 – General Dentistry; 3 – Dental Hygiene; 4 – Front desk/Patient waiting room; 5 – Storage; 6, 9 - Dentist Office; 7 – Lab; 8 – Conference room and 10 – rest of the clinic.)

3.2 Processes

The study of the outpatient clinic gave an overview of the patient flow in the system and is depicted in Figure 3. The processes at the Minneapolis VA dental clinic can be grouped into appointment scheduling, reception, treatment and consultation.

a) Appointment scheduling process

Requests for appointments are made at the reception area either in person or on the phone. The care provider via a computer order sent immediately after the patient's appointment can also schedule appointments. Based on patient's medical condition, urgency, the care providers' schedules and resource availability, patients are scheduled for treatments/consultations. Based on the appointment, patients at dental clinic are identified as

- New patients, who visit the clinic for the first time or with a new medical complaint,
- Follow up patients, who are either in the process of treatment or are visiting for a periodic checkup as suggested by the dentist
- Emergency/Walk-ins, patients suffering from severe medical conditions like, excessive bleeding or pain and those who need immediate care can visit the clinic without prior appointment. Compared to other medical specialties, the dental clinics face fewer life-threatening issues on a daily basis.

At the dental clinic, receptionists at the front desk generally schedule appointments for treatment. They match patient schedules with care provider's availability using scheduling software. When a patient is scheduled, they receive a receipt of the appointment date and time along with details of the care provider they are consulting. The scheduling system at VA clinic follows an individual block and variable interval system. Double booking of appointments are avoided.

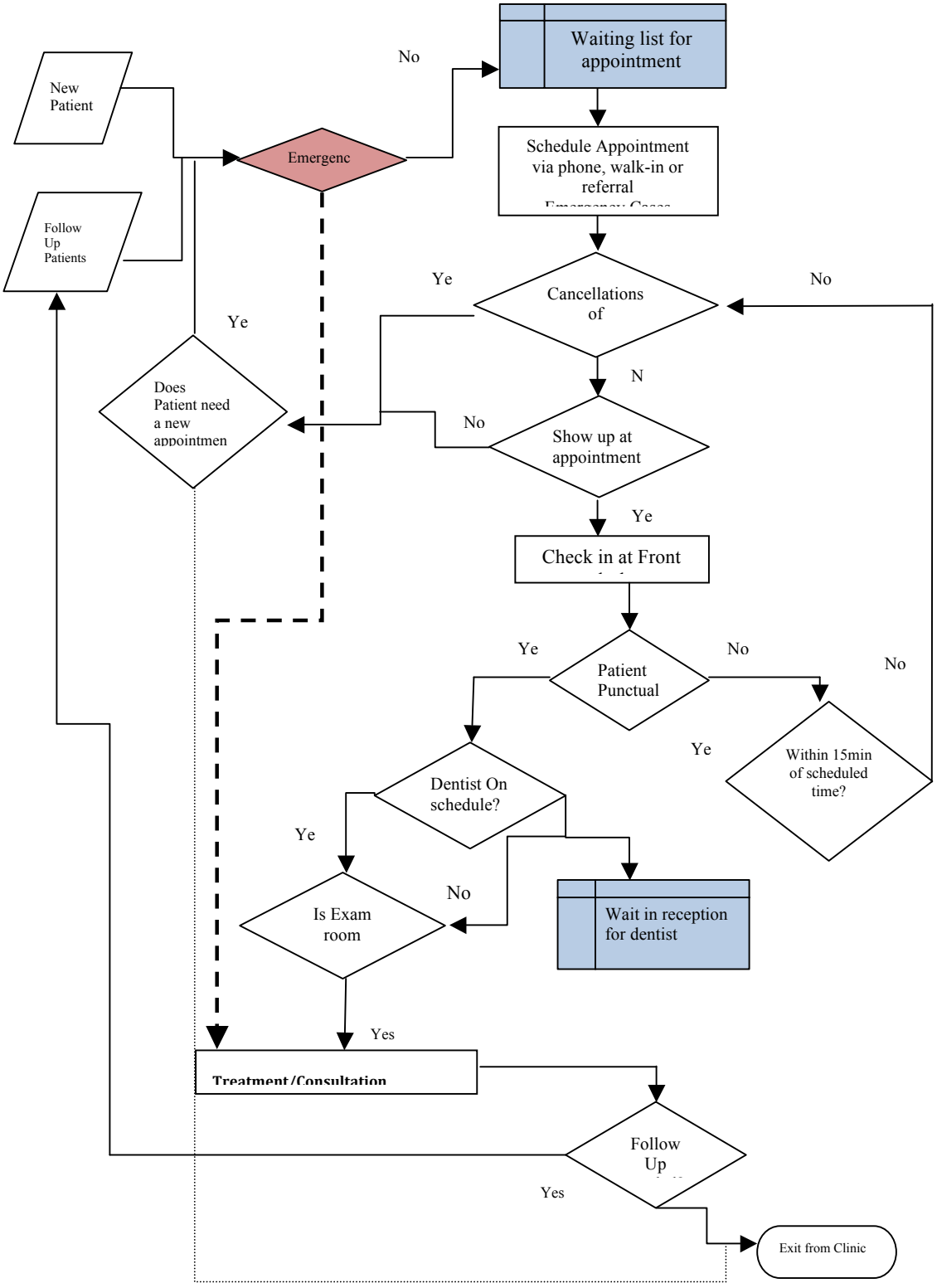

Figure 3: Process flow diagram of VA Dental clinic

The clinic issues appointments from 8:00 am to 3:00 pm on all days excepting weekends and holidays. The dentists and medical staff work from 7:30 am to 4:30 pm or till all the scheduled appointments have been met for that particular day. Each patient gets an individual appointment to match the type of medical procedure required. For new patients, the appointment duration is determined based on the guidelines from the national VA administrator. In case of follow-up patients, the appointment length is chosen by the care provider and scheduled by the receptionist. The appointment length can be 30 min, 60 min, 90 min or 120 min. While most of the morning appointments include consults and follow-ups, treatment procedures requiring more time are scheduled in the later part of the day.

Patients sometimes cancel their appointment and request new appointments. At times, patients may fail to show up for their appointments. Cancellations and no-shows create gaps in the appointment schedule that are hard to fill on short notice. The cancelled appointments typically remain unused. Receptionists also deal appointment cancellations and reschedules.

b) Reception Process

The reception process in the appointment system includes check-in and check-out at the front desk, waiting time for appointments and general assistance. Patients are expected to arrive 15 minutes before the scheduled appointment. Upon arrival, new patients fill in forms briefing their medical conditions, medical history, pain symptoms, list of allergies, details about any ongoing medication, insurance and billing details for the medical records at the clinic. Previous medical test reports and prescriptions are attached to the details submitted. This process is one time activity specific for new patients to the clinic or for those returning patients with new medical complaint. Failure to register at the desk before the scheduled hour cancels the appointment. The entire check in process takes only a few minutes on an average at the clinic studied. For medical emergencies, specialized care providers conduct minimal formalities at the front desk to assure immediate treatment.

c) Treatment and Consultation

Care providers treat patients based on the schedule and the sequence of arrival of patients at the clinic in case of a tie. The sequence in which patients are treated or called from the waiting room depends on the schedule and waiting in the common room are called by the care provider

At the end of consultation, one of the following dispositions is made:

- Treatment is completed and patients are not referred for future appointments (no need of follow-up)

- For new patients, after initial diagnosis treatment plan is prepared and patients are given appointment for return visit(s) if needed. For patients amidst treatment, return appointments are scheduled or rescheduled as per the dentists and patients convenience.

- In case of regular follow up which is suggested for overall hygiene, patients are given a verbal timeframe and are asked to take an appointment before the prescribed time.

- Patients are referred to dentists from other VA clinics or private practitioners in case of which no follow up appointment is made at the current VA clinic.

- In few cases, no decision is made on further treatment as the patient needs medical authorization from VA [9].

3.3 Current System Metrics

The VA dental clinic has been studied and its processes understood. Time studies were conducted over several days to measure the performance of the clinic.

I. Number of Patients

VA dental clinic manager, Lou Plevell provided data on the number of patient appointments scheduled on ten random days in the months of June-August. A total of 705 patients are seen on 10 days as shown in Figure 4. Based on this information and the data

collected at the clinic, the average number of patients seen on a daily basis is approximated to 70. The number of appointments and patients treated is higher before vacation or holidays.

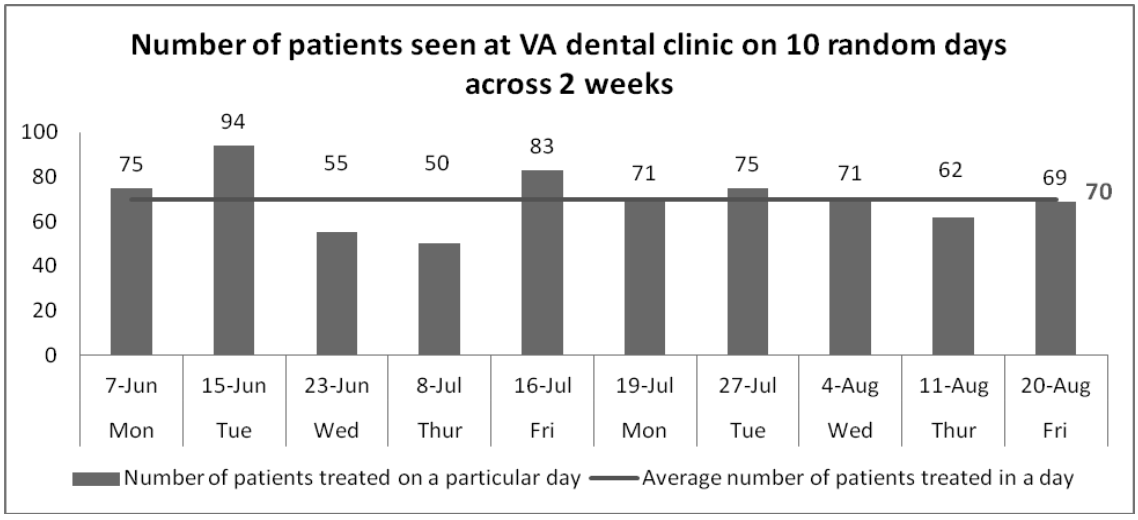

Figure 4: Number of patients seen at the Minneapolis VA dental clinic

The management statistics also noted that out of 803 appointments issued in the first two weeks of May, 172 appointments remain unused. This means that 21 percent of the appointments went unused during the particular month. The clinic reports showed that in the month of January in the year 2010, 322 open slots were left unused. Unused appointments are a result of appointment cancellations, patient no-shows, scheduling errors and inefficient usage of computerized scheduling software in place at the clinic.

II. Scheduled appointment durations

The VA clinic schedules patients using four different fixed appointment lengths – 30, 60, 90 and 120 minutes. The length of the appointment is decided by the dentist or receptionist based on the nature of the procedure. New patients and dental hygiene appointments are assigned a standard appointment of 1 hour. Crown and bridge procedures filling caps and root canal therapy vary in time and are specific to the patient condition. The treatment procedures may vary between 90 or 120-minute appointments.

Time Slot	Number of Patients	Frequency
30 minutes	13	27%
60 minutes	31	63%
90 minutes	1	2%
120 minutes	1	2%
Walk In Appointments	3	6%
Total	49	100%

Table 1: Frequency of appointments based on appointment length

The time measurements at the outpatient clinic are tabulated and analyzed. Table 1 lists the frequency of appointments based on the appointment length. As discussed above, 90 percent of appointments are of 30 minute and 60 minute duration. The remaining appointments constituted of 90min, 120min and emergency walk-ins. It should be noted that more than sixty percent of the appointments are of 60 min. The number of emergency cases is random and hence an average of 5 walk-ins per day is included in the simulation model are random.

III. Patient Punctuality

Patient timeliness is a key factor which impacts the schedule efficiency. When patients keep appointments and arrive before the scheduled time, it assists in smooth workflow and. Patient punctuality is defined as the difference in time between patient's arrival to the clinic and the scheduled appointment. Patients are encouraged to arrive a little earlier than their appointment to avoid delays at the registration. Arriving too early to the appointments is discouraged since it leads to cluttering of clinic space and reflects negative effect on hospital management. While arriving exactly at the appointment hour or a little later delays the treatment process. It adds to care provider and hospital staff's idle time and thus affects the overall clinic efficiency.

Patient timeliness has been measured several times before and research shows that on an average, patients arrive 0 to 15 minutes before the scheduled appointment. The time studies at the clinic suggest a similar pattern (Figure 5). More than eighty percent of

the patients are punctual and arrived earlier to their appointments. Only 8 among the 49 patients were late for their appointment. In general, a delay of 10-15 minutes from the scheduled time leads to cancellation of appointment. However, the two patients who arrived later than 15 minutes to the scheduled appointment were treated at the hospital.

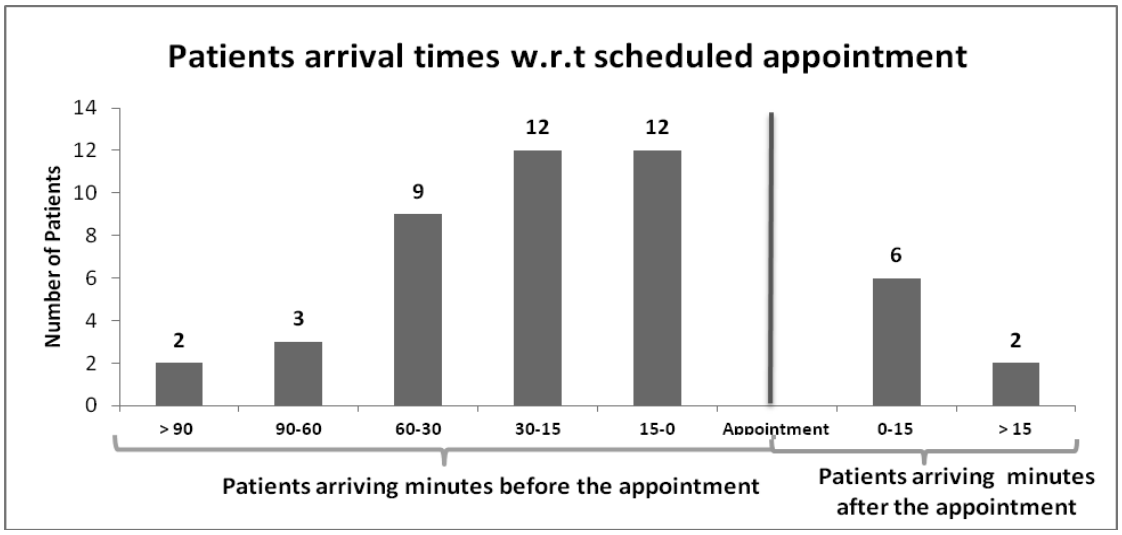

Figure 5: Patients arrival with respect to scheduled appointment

On an average patients arrive 21 minutes before their appointments. There were 2 patients who arrived hours before their appointment (2hours and 4hours respectively) and got treated before the schedule. However these instances were considered rare and were excluded from calculating the metrics.

IV. Check-In time

Checking in or registering at the front desk is a common practice in most of the clinics. All patients, excepting emergency walk-ins, are expected to report their arrival at the front desk and submit the necessary information. Receptionists sitting at the front desk review patient's appointment and confirm the same. They also assist new patients in filling personal and medical details for the hospital records.

Registering at the front desk takes about a minute or two depending on the patient queue, availability of staff. 2 receptionists handle the duties of the registration process and assist patients over phones and in person. The average time taken for patients to

check in at the VA dental clinic is about 1.3 minutes. Seventy percent of the patients checked in in less than a minute as shown in figure 6. There is one instance where the patient had to wait for 10 minutes before being assisted by the front desk.

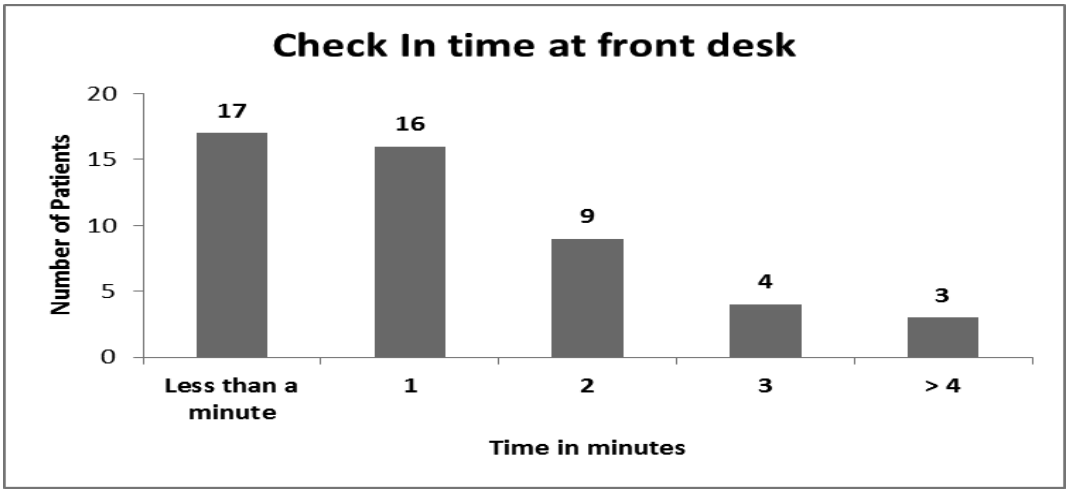

Figure 6: Waiting time at the check in counter

V. Clinic Tardiness

Clinic tardiness can be defined as the difference in time between the scheduled appointment and the actual consult given the circumstance that patient is punctual. When the care provider arrives late for the first appointment, it directly affects the internal waiting time of all the patients scheduled for that particular day [8].

Another major factor which contributes towards patients waiting times is the time spent by care providers doing non-clinic work. Study shows that on an average 41 percent of the care provider's time during a session is not spent on patients [12]. Interruptions during appointments are common. Care providers have administrative responsibilities like documentation work, group meetings, attending seminars or learning software technologies for maintaining of reports interrupt the regular schedule. Social interactions with staff and other care providers, phone calls, preparing notes for consults, comfort breaks also work towards lateness of appointments.

It has been observed that the care providers in dental clinic at VA were also data collected at the VA clinic suggest both the scenarios of care provider punctuality.

The bar graph in figure 7 shows the patients treated earlier as well as later respective to the scheduled appointments. The table below gives the detailed statistics of the care provider punctuality. It should be noted that nearly fifty nine percent of patients were delayed due to care provider punctuality. Out of 27 patients whose appointment got delayed, 6 of them were late for their appointments. On an average patients appointment was delayed by 12 minutes ranging up to 65 minutes at maximum. The treatment was delayed by less than 10 minutes for 17 of the 27 patients while other patients had to wait for longer times.

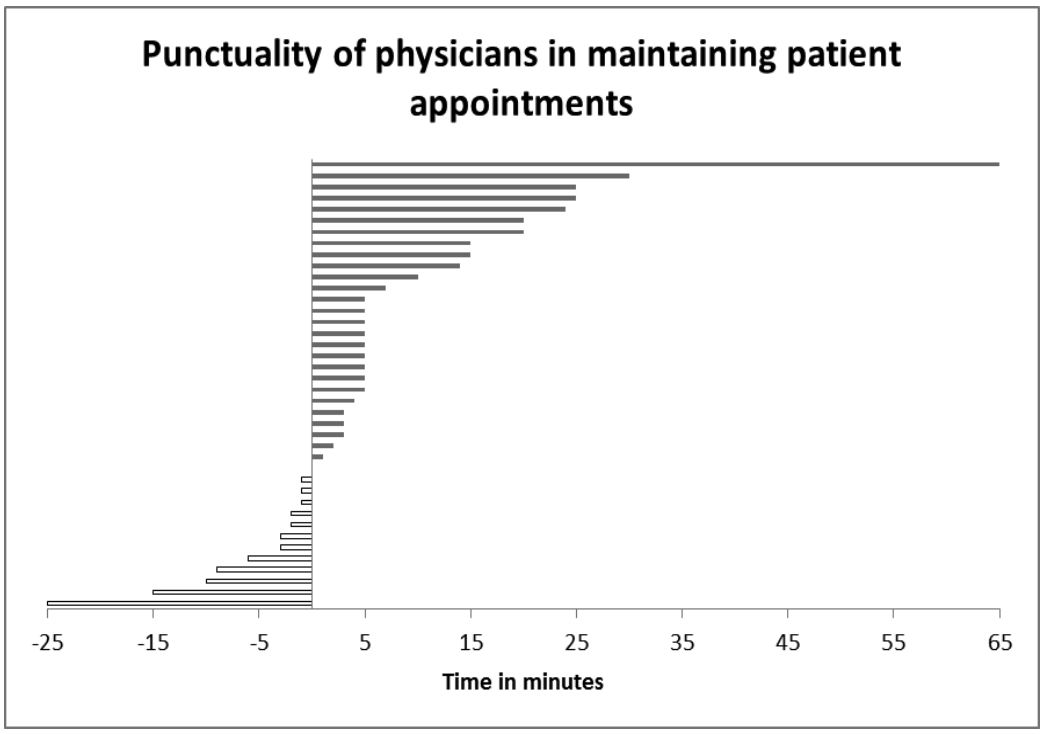

Figure 7: Bar Graph representing the punctuality of care providers (N=40)

The clinic also treated patients before the scheduled appointment. There are two exceptions where patients came hours before the scheduled appointment and got treated. The patient who arrived nearly 3 hours before the scheduled appointment (outlier marked

in figure 8 – earliness of appointment) has been excluded from statistic calculations in table 2.

	Earliness of appointments	Lateness of appointments
Number of patients	19	27
Mean(in minutes)	4.3	12.26
Median (in minutes)	1.5	5
Standard Deviation	7	14
Patients arriving punctual to appointments	N/A	6

Table 2: Descriptive statistics of care provider punctuality

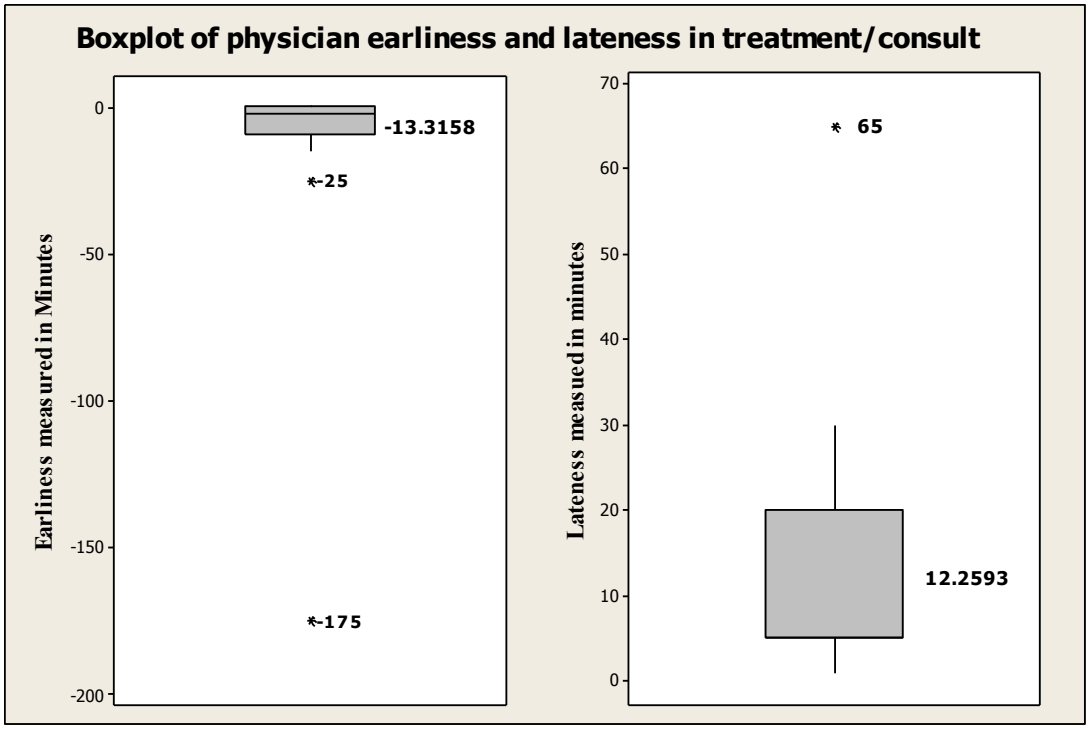

Figure 8: Boxplot representing care provider punctuality to appointments

VI. Consultation Time

Consultation or service time is defined as the time during which a patient claims a doctor's attention, or at least prevents him from seeing the next patient (Bailey, 1952). The gross consultation time consists of

a) Preparation time - in which the doctor reads the patient's status record and test results and/or prepares material requirements for treatment

b) Net Consultation time - which we define as all time the patient is in the consultation room, and

c) Miscellaneous - This includes cleaning the room and prepping the room for next appointment. Care providers also have to finish administrative formality (if any) related to the cases.

As observed in the VA clinic, care providers didn't allot separate time for preparing for the consult. Reviewing the medical records and test results were done simultaneously during the consult. Data was collected on the net consultation times and the cleaning times. The mean and variances of the service times for the four different appointment types is given in table 3. The frequency of various appointment types is shown in figure 9.

Scheduled Appointment time	Actual Appointment time				
	Number of appointments	Mean (in minutes)	Standard deviation	Minimum (in minutes)	Maximum (in minutes)
30 minutes	13	42	28	7	120
60 minutes	31	54	22	17	104
90 minutes	1	87	N/A	N/A	N/A
120 minutes	1	110	N/A	N/A	N/A

Table 3: Service times of patients based on appointment lengths

The average time spent by a care provider on 30 minute appointments is greater than the scheduled time. Only thirty percent of the appointments scheduled for 30 minute appointments finished within the timeframe. There is a high variability in the consultation times of 30 and 60 minute appointments as shown in table 3. On an average, each 30-minute appointment extended 12 minutes over the scheduled appointment and has a standard deviation of 28 minutes which is high. 60-minute appointments also have a high variability and the standard deviation is 22 minutes. The boxplot of the appointment durations of 30 minute and 60-minute appointment is shown in figure 10.

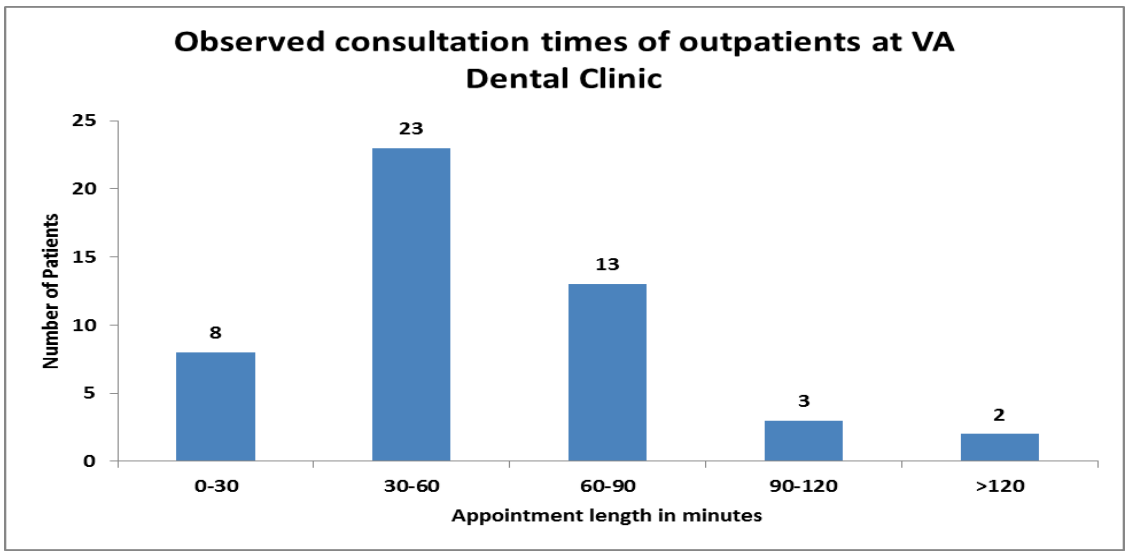

Figure 9: Observed Consultation times of outpatients irrespective of appointment types

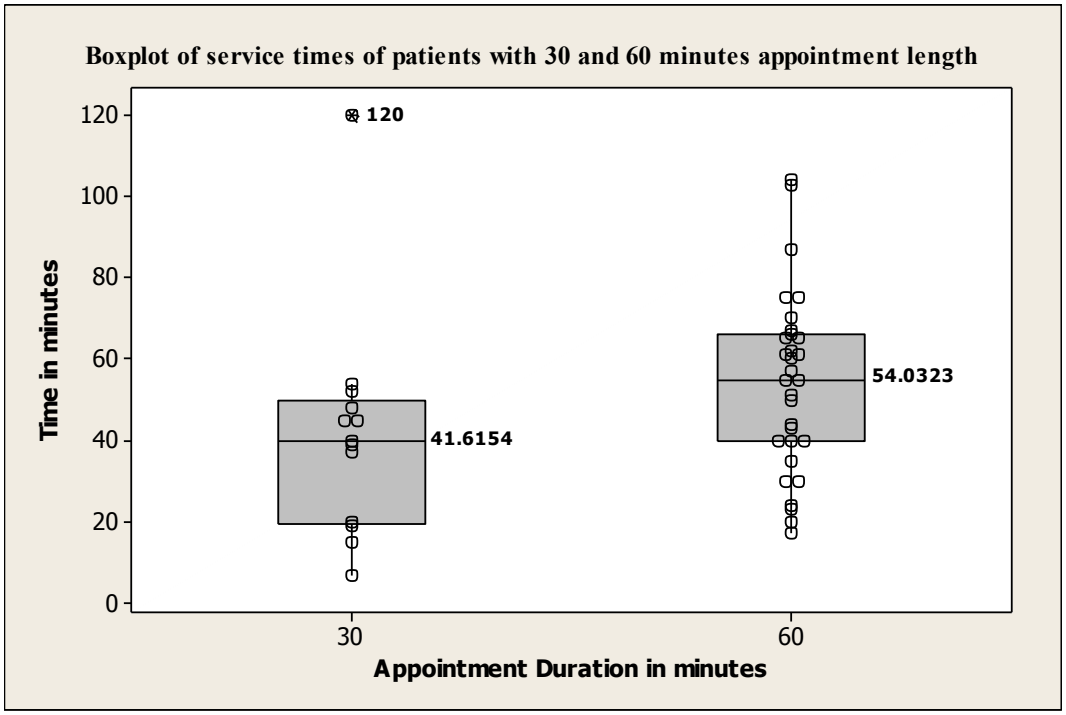

Figure 10: Boxplot of consultation times of patients with 30 min and 60 minute appointment lengths

3.4 Shortcomings of the current appointment system

Based on the metrics of the current system the following are the major shortcomings observed, changes to which would help in improving the productivity and resource utilization of the clinic.

- The access delay for appointments is approximately 60 days from the date of request. It is a major cause of concern and dissatisfaction among patients and the clinic management.

- The clinic reported 322 and 172 unused appointment slots in the months of January and May respectively. Issues in using the current appointment software, double booking and manual booking of appointments are the reasons errors cited by the management for the non-utilization of appointments. This underutilization of appointments shows that the clinic is not being functional to its maximum capacity and there's scope for improvement.

a. The clinic faces 21 percent of no-shows and appointment cancellations which are higher compared to the 0-15% cancellations observed in other clinics. The long access times for appointments are one of the main reasons for cancellation. It is highly probable that the patient gets cured or treated (by emergency care) within that timeframe.

   - Frequency of over utilization/underutilization of appointments is observed in the clinic as shown in figures 11 and 12. 69 percent of the 30 minute appointments exceeded the appointment length, while 42 percent of the 60 minute appointments didn't finish in the allotted time. The reasons for exceeding the scheduled appointment time are the mismatch between the treatment procedure and the appointment type, dentist timeliness in finishing the appointment within the timeframe or issues with the resource allocation.

   - There is a concern about care providers' punctuality in arriving at the clinic and the percentage of time spent for interruptions. The management observed that most of the morning appointments are delayed due to care provider tardiness.

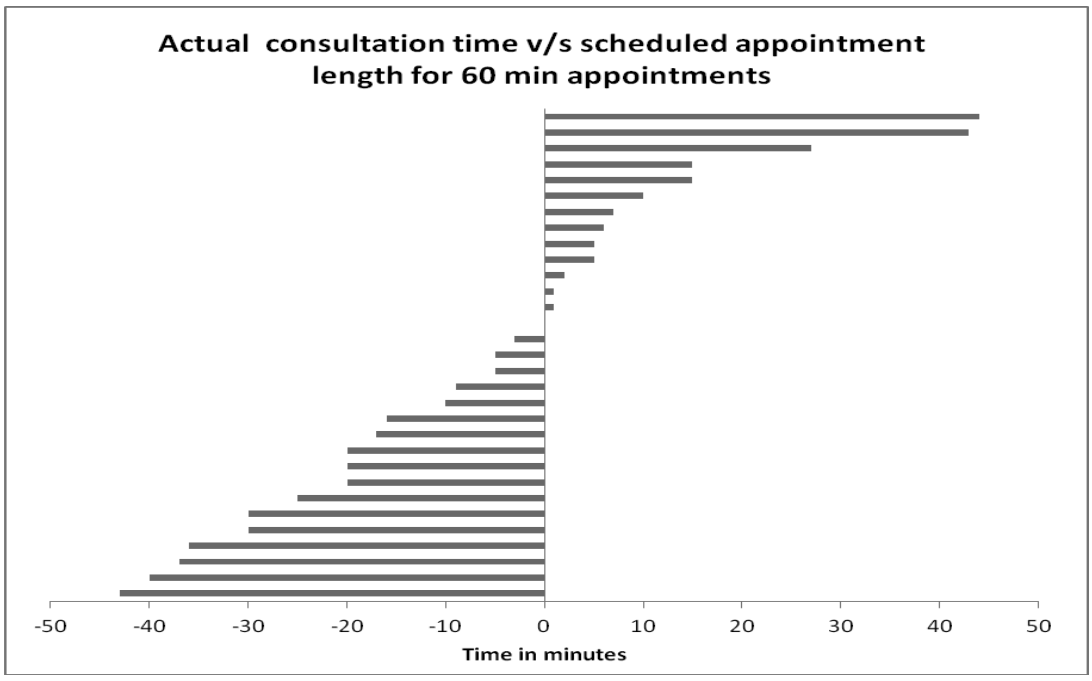

Figure 11: Actual consultation time v/s scheduled 60 minute appointments

3.5 Research Questions

The following research questions have been formulated in order to understand and improve the scheduling system of VA dental clinic.

a) To quantitatively understand the research problem the performance metrics of the existing system are calculated which include – the number of patients seen on a daily basis, the average waiting times, utilization of clinic staff and resources.

b) Which modeling techniques should be used to replicate the system for evaluation of the proposed alternative appointment schedules

c) Determining the input and model parameters like arrival distributions, inter arrival times, waiting time, process/service distributions for modeling the appointment system

d) Do multiples of hour long appointments have less waiting times compared to appointments with multiples of 30 minute duration?

e) What is the optimal time duration for an appointment

f) What sequence rules apply best for optimizing the patient wait times

3.6 Alternate appointment configurations

The total time Appointments are usually given in multiples of a basic slot. The duration of the appointments is based on the treatment procedures applicable to the patient. Scheduling system with multiple appointment types increases the complexity of the appointment system. Schedulers are often confused when trying to match the patient diagnosis with the optimal appointment type. Estimation and forecasting of patient demand based on appointments is more tedious and difficult with numerous appointment types. By employing only a single queue for urgent and routing care, accurate predictions of the patient demands can be made and the waiting times reduced [14]. Having fewer number of appointment types are particularly helpful in cases where the appointment times are not decided by the care providers.

To see the effect of having fewer number of appointment types, two configurations are proposed. Both the scenarios use only two appointment types as against four used by the clinic. In the first scenario, the appointments are of 60 and 120 minute durations while in the second scenario, 30 and 60 minute appointments are used.

The productivity of the clinic is also affected by the uneven allocation of resources. In normal cases, patients are assigned to the dentists at the time of appointment and aberrations like no-shows, appointment cancellations can negatively impact the resource utilization. There can also be dissatisfaction among the dentists due to the uneven allocation of patients by the receptionists. This problem can be avoided by allocating the resource at the time of appointment from the pool of resources depending on the availability. By employing this method, it is ensured that waiting times are reduced and there is an even distribution of work among all the resources. The third appointment

configuration utilizes this method by using a pool of hygienists and allocating them to the patient at the time of the appointment.

I. Reducing the number of appointment types

Presently the VA dental clinic accommodates appointments of 30, 60, 90 and 120 minute durations. The clinic authority wanted to do away with the four different kinds of appointments as many technical issues from having these four appointment types often resulted in the underutilization of the resources.

	30 min	60 min
Number of appointments	13	31
Mean	42	54
Median	40	55
Standard deviation	27.96	22
Percentage of appointments which exceeded the appointment length	69%	42%
Lower bound of 95% confidence interval of mean	25	46
Upper bound of 95% confidence interval of mean	55	62

Table 4: Appointment statistics of 30min v/s 60 min

The frequency of the appointments and the mean consultation times has been studied. It has been observed that 30 and 60 minute appointments attribute to nearly 90 percent of total appointments. The statistical analysis of these two appointment types is given in table 1. It is seen that the average consultation time of the 30 minute appointments is 42 minutes which is 12 minutes longer than the scheduled time. The standard deviation of this appointment type is 27.96 minutes which is an indicator of the high variability. Figure 9 compares the actual consultation times of patients with 30 minute appointment lengths against the scheduled time. The patient's consultation times ranged from a minimum of 7 minutes to a maximum of 120 minutes for the 30 minute appointments. It is also observed that 69 percent of the 30 minute appointments extended over time. To reduce the variability of the 30 minute appointment, the new model combines the 30 minute and the 60 minute appointments to a single appointment type of 60 minute duration.

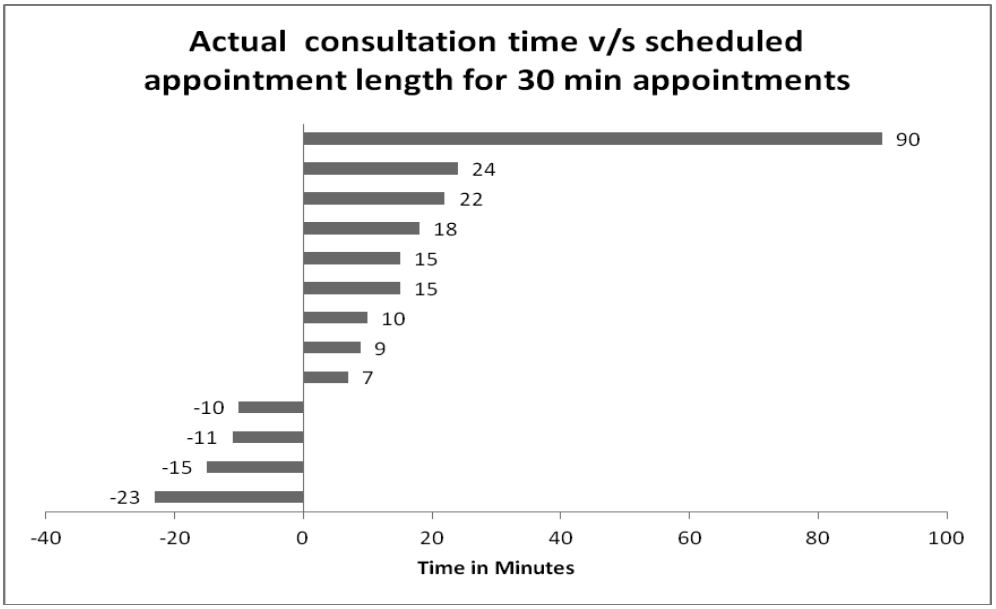

Figure 12: Actual consultation time v/s scheduled 30 minute appointments

Another observation made by the clinic management with respect to the current appointment system was the non-usage of 30 minute appointment slots followed by the 90 minute appointments. To eliminate such scenarios and for better utilization of appointment slots, an appointment system consisting of only 60 minutes and 120 minutes slot is modeled.

The second appointment configuration is also based on reducing appointment types. In this configuration the appointment system is divided into slots of 30 and 60minutes. As observed from the sample collected, the number of appointments with 90 minute and 120 minute as appointment length were very few and accounted for 4 percent of the total appointments. Using 120 minute appointments might result in a number of cases where the appointment is completed well before the scheduled end time which would drastically affect the resource utilization. There are a number of cases where the consultation was completed within 30 minutes as shown in figure 36. Hence in cases where the appointment variation is so high, having only 60 and 120 minute appointments might lead to long idle times for care providers at the clinic.

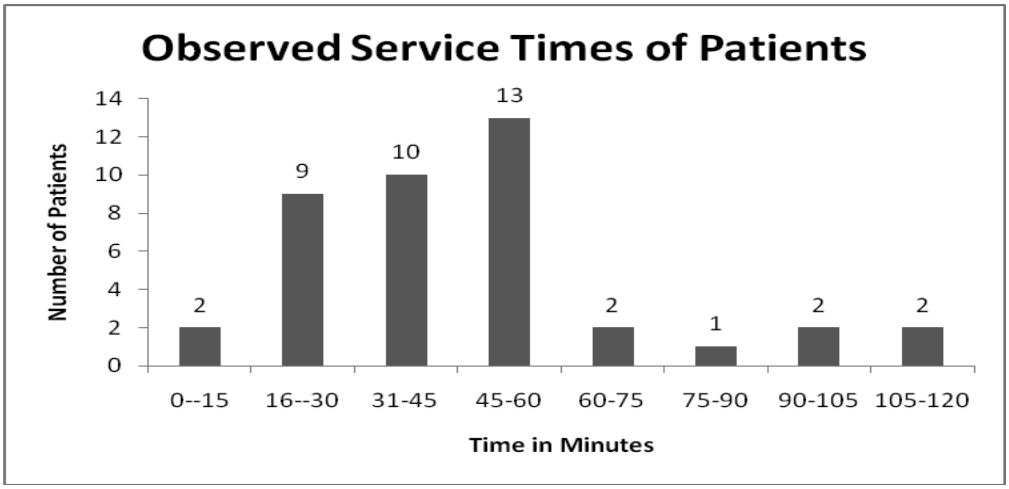

Figure 13: Observed patient times in slot of 15 minutes

Another motivation behind the 30-60 minute appointment configuration is the issues with longer consultation hours. Longer dental procedures are considered to be stressful by the patients as using jaw muscles for opening the mouth for extended time can be a lot of strain. Hence, patients prefer shorter appointment durations.

II. Pooled group vs Individual doctors

One of the most common scheduling procedures observed across clinics is to assign a particular care provider to a patient at the time of scheduling. In cases such as these, on the day of appointment if the care provider schedule gets delayed it directly effects the patients wait time. Exceeding patient appointments, unexpected emergency walk-ins, administrative work are few reasons which can delay care provider's schedule.

A better practice of scheduling involves pooling appointments based on specialty and assigning care providers on the day of appointment based on patient arrival time and care provider availability. In this method, at the time of scheduling appointment, the patient is referred to the clinic than to a particular dentist. Like any other appointment system, this configuration has its merits and shortcomings. This kind of scheduling reduces the patient waiting times and increases care provider utilization as seen in NHS modernization agency [11]. The distribution of patients across the care providers is more even.

The main drawback of this practice is with the follow-up appointments. Most of the dental procedures are scheduled in two to four hour blocks and more than one appointment is necessary to complete the treatment procedure. Patients prefer to visit the same care provider while continuing their treatment. Studies show that meeting the same care provider/dentist for a follow up saves a lot of time and improve the patient-care providers interaction.

Hence, to override the drawback of this configuration, it is proposed to test this configuration for dental hygiene appointments where follow up appointments are usually independent.

Chapter 4

Research Overview

The scheduling system at the outpatient department of the dental clinic has a complicated structure involving utilization of personnel, processes and other resources. A well-established scientific methodology has been followed to study the scheduling practices of the dental clinic. The methodology included observing patient flows, interviews with hospital staff and management, data collection, simulation modeling, testing and validation of the models which were built to quantify the uncertainty involved.

4.1 Observations

Several visits were made to the dental clinic during the course of the project for observing the patient flow trends. The first few visits were intended to observe the general behavioral aspect of the system and did not follow any rigorous structure. The visits aimed at understanding the various departments and layout of the clinic, the hierarchy of the management system, equipment used for therapy, process flow and the allocation of space for various departments.

4.2 Interviews

In order to effectively understand the flow processes, it was necessary to interact with the people concerned. Interviews were conducted with various staff members representing different branches of the organizational structure including front desk receptionists, care providers, clinic managers and chief of dental service, Dr. Templeton. The questions were open-ended and followed a free style to understand the issues and shortcomings of the present process.

Interviews with front desk receptionists gave more information on the present scheduling system and its shortcomings. Of particular importance were the interviews with Dr. Templeton and Louis, the general manager, which helped us, understand the organizational structure better and gave an insight into the yearly goals set by the management. A very interesting aspect that came out of the interviews was that the

hospital management could pin point the exact reason causing the delay in the scheduling structure. Having understood the root cause, namely the lack of efficiency in using the current software system deployed, the next step was to understand the other factors which were detrimental to the smooth working of the system.

4.3 Data Collection and Analysis

Data collection was an important step in gaining a quantitative understanding of the different parameters involved. It also served as the source of input for the simulation models that were developed later. Time studies were conducted over several days to collect data that included the time of appointment, duration of appointment, the time reported by the patient at the clinic, the start time of the checkup and the time he/she left the clinic. Time taken to check-in at the front desk and the time required to prepare the room for next patient were also timed.

Professor Hayes and Shahrzad Grami had collected data of the entire process using induct cards. Cards were printed and distributed to patients as they arrived at the clinic. The cards were then attached to the patient's file and the receptionist and dental assistants were requested to fill in the details pertaining to the appointment as the patients moved along the process. The cards were collected as the patients left the clinic after their consultation. The clinic manager, Lou Plevell, provided the total number of appointments the clinic scheduled on those days. More statistics about the clinic were shared which helped in formulating a few performance parameters. Once the data collection was complete, data analysis was done on Excel and Minitab. Data from the induct cards is attached at the end of this document (Appendix I).

4.4 Experimental design and Simulation Model

To improve the scheduling at the VA dental clinic, the current system has been studied and evaluated. To examine patient wait times and identify process bottlenecks, simulation and queuing models have been designed. The simulation models were then used to forecast patient demand, measure the impact of changes due to process

variability, resource utilization and investigate complex relationship of different variables used in the appointment scheduling.

The models created in the thesis, captured the flow of patients through different care pathways in the clinic while incorporating the factors of variability and uncertainty in patient demands. The models were tested against the current clinic settings and various performance parameters like wait time, number of patients seen, room and care provider utilization were measured.

The output of the modeled simulations can be used in improving the performance of the current system, reconfiguring the process flows or system designs to match the supply, developing new systems to cater to unmet needs, without altering the present system. Three new appointment configurations have been suggested to the present model based on logical reasoning and statistical data obtained from the simulation model.

Chapter 5

Simulation Model

To improve the appointment scheduling process at the VA dental clinic the current system has been modeled based on the metrics collected at the clinic. Alternate appointment configurations suggested to the clinic have also been tested with this model. The performance of the model has been evaluated and the output results were compared to the metric of current system. This chapter details the design, assumptions, and limitations of the simulation model. The simulation model is built using the Basic Edition of Rockwell Arena version 11.

5.1 Simulation model description

The simulation model for the clinic is built using software package ARENA based on the data collected by Shahrzad Grami and Professor Caroline Hayes at VA dental clinic. The model represents the process flow at a single outpatient dental clinic. The outpatient system includes patient arrival, queuing for processes, waiting times and treatment procedures. The model is a terminating system, wherein the patients exit the system after treatment. Schematic of the VA dental clinic system is shown in figure 14.

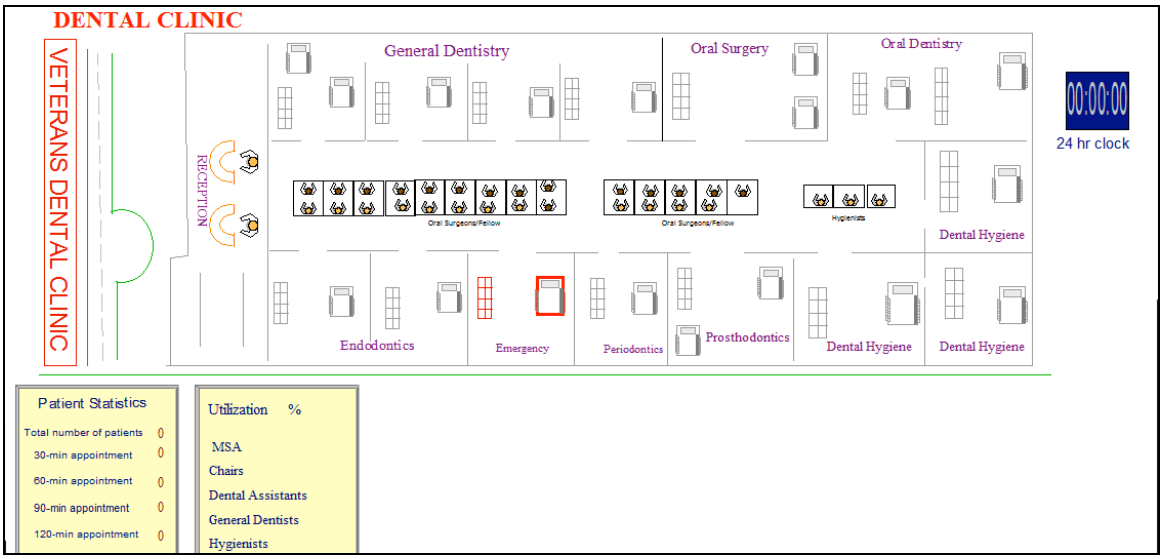

Figure 14: Simulation model

The simulation model also displays a clock and a counter which keeps track of the number of patients based on their appointment type. A table displaying the instant utilization of the resources at the clinic is also shown. Detailed description of the model in terms of the entities, resources and processes is given later in this chapter.

An important feature of the model is that one can see the process flow as it happens in the simulation. The movement of patients from the registration to exit can be visualized in the model. Based on the medical condition, the patients arrive either in ambulance or personal conveyance. The rate of arrival of patients is correlated to the rate of arrival of vehicles. The model clearly shows the queuing at the registration counters and patients waiting in the lobby for treatment procedures. The current state of the resources can also be identified by the color used to represent the resource. Figure 15 gives the colored icons of the resources at each stage.

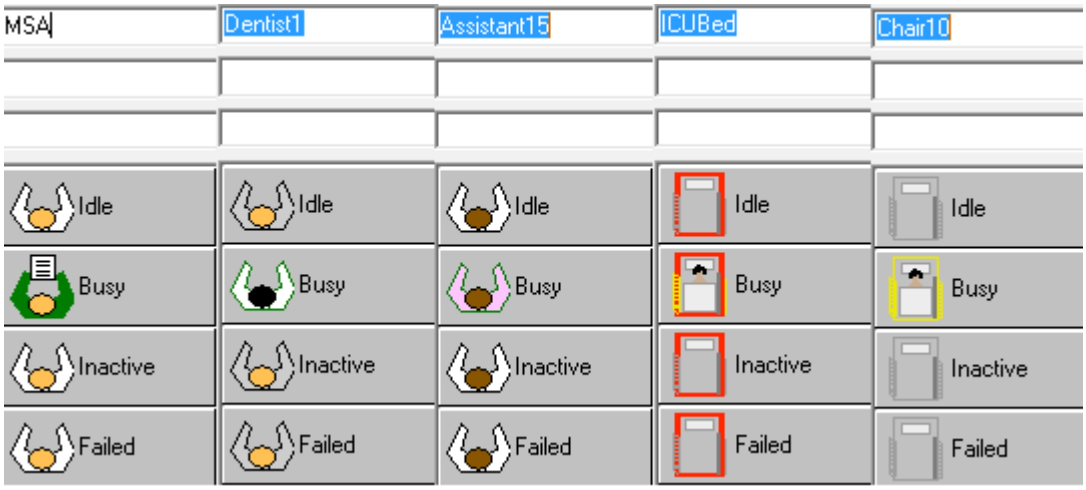

Figure 15: Animations of resources based on their state of utilisation as modeled in ARENA

5.2 Model scope and limitations

The simulation model is a replica of the appointment system in place at the VA clinic. As it is practically impossible to model all the details of the real system, the simulation model has the limited scope. The assumptions and limitations are discussed as below.

- The study includes information about only those patients who are treated at the physical location of VA dental clinic, Minneapolis. During the discussions with care providers and management, there was reference made to cases where care providers travelled to other VA clinic centers to treat patients. However, no data was collected regarding the number of such treatments, frequency of such events or interruptions or delay of patients treated at the Minneapolis clinics due to same. The management at Minneapolis center is actively adopting Telemedicine technology to cater to patients in the VISN network. The dental tele- consults are also not included in the study.

- The VA dental clinic is teaching institution where professionals undergo training in chosen specialization as a part of completion of residency. Residents working as part-time dentists handle few independent cases are also included in the study. They tend to need more time compared to experienced doctors to accomplish the same tasks.

- The analysis and interviews were limited to only few care providers in the clinic and hospital management. Also, not every practitioner was observed individually to calculate the utilization rates.

- The medical privacy was strictly followed. No personal information regarding patients or care providers was collected or published in the study. None of the patients were interviewed or asked any questions as a part of the research. Persons collecting the data tried to understand the process flow by standing at distance and observing silently, without interrupting the process. The quality of the service levels is based majorly on concept than any numerical information.

- Our data sample includes the observations spanned across 3 random weekdays, a bi-weekly report, and a sample of patient's data over 10 random days obtained from the management. The data collected is restricted and might not reflect the actual system.

- In future research studies, more extensive data collection along with patient expectations should be included in the project to improve the scope and understanding of the project.

- The model simulates the behavior of the outpatient dental clinic. Any consult made outside the VA dental clinic are not included in the model.

- The simulation generates patients based on theoretical probability distributions. The model is unable to predict the variability in the demand of patient arrivals before the holiday seasons.

- Patients and dentists prefer certain days and appointment times for treatment procedures. However this model schedules patient at the earliest and neglects the patients and care providers preference of date and time.

- The access delays for appointments which are a major concern for the patients and hospital management is not depicted in the model.

- Doctors and patients arrive early, on time or late for their appointments. The model explicitly simulates the arrival processes of patients and doctors using theoretical probability distributions. A clinic session starts when the doctor and at least one patient have arrived. Negative waiting times might occur if the patient arrives early and the doctor is available for the consultation. However, in the model a clinic session never starts more than ten minutes before the scheduled appointment time of the first patient. This reflects reality as far as possible.

- The study classifies patients based on the variability of service times and treatment procedures. The processing times of patients differs between new and review patients. However no information was collected on the percentage of patients this aspect is included in the model.

- Patients who cancel their appointments and patient, who do not show up, may request a new appointment at another day. However, the model deletes these patients. The arrival rates are adjusted as the percentage of cancelled appointments and no-shows.

5.3 Model Parameters

The model runtime is based on the working hours of the clinic with each run representing a day's work. The dental clinic schedules patients from 8:00am until noon, then from 1:00pm until 3:00pm with one hour lunch break in between. However the clinic works till the last patient exits the system. All the times are represented in minutes. Each model with a particular combination of attributes is replicated for 1000 simulations. The model terminates only after 5 pm and after all the work in progress patients are treated by the clinic.

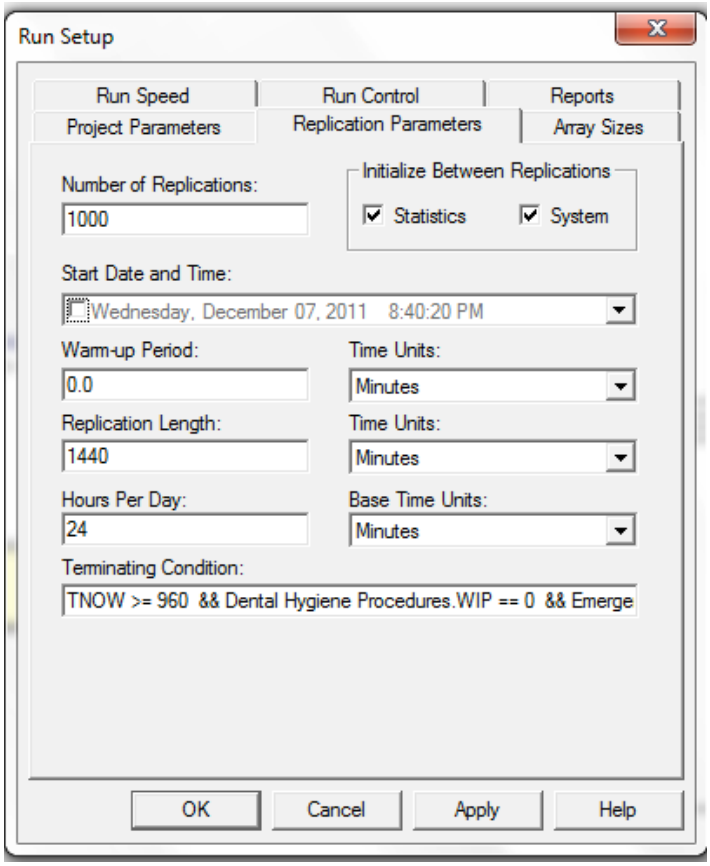

Figure 16: Simulation model parameters

The detailed description of all the simulation is discussed below.

a. Patient Arrivals

Patients are the input to the system. Patients generated in to the system are through two separate modules – Walk-ins and scheduled appointments.

a) Scheduled appointments - The dental clinic issues appointment from 8:00 am to 3:00pm. The first patient is created at 7:30 in the morning as the patients arrive approximately 20 minutes before the appointment. The schedule by which patients enter the system is given below in figure 17. No appointments are scheduled during the lunch hour which is usually from 12-1pm. the last scheduled appointment for any given day is 3:00 pm.

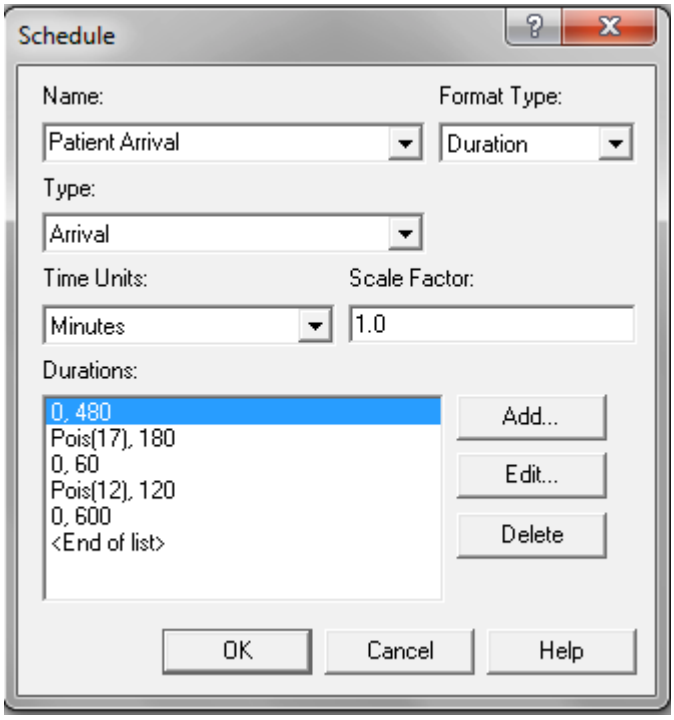

Figure 17: Patient arrival schedule as modeled in ARENA

The total number of patients treated/consulted at the VA dental clinic on a daily basis averages to 70. More appointments are issued by the clinic in the mornings

compared to afternoon session. The patients are further grouped according to their appointment types.

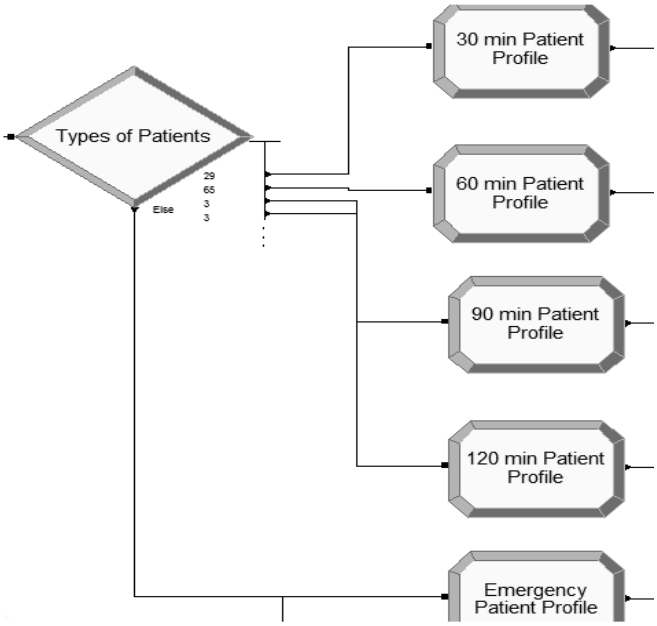

Figure 18: Entities grouped based on appointment type

b) Emergency patients are created separately from the scheduled patients. The first walk-in patient is created at 8:00 am and time between the subsequent arrivals follows a uniform distribution. Walk-ins are accepted till 4:00 pm on any working day or depending on the emergency till the clinic closes. But the sense of urgency is limited in a dental clinic, unless it's a tooth fracture or excessive bleeding which is rare.

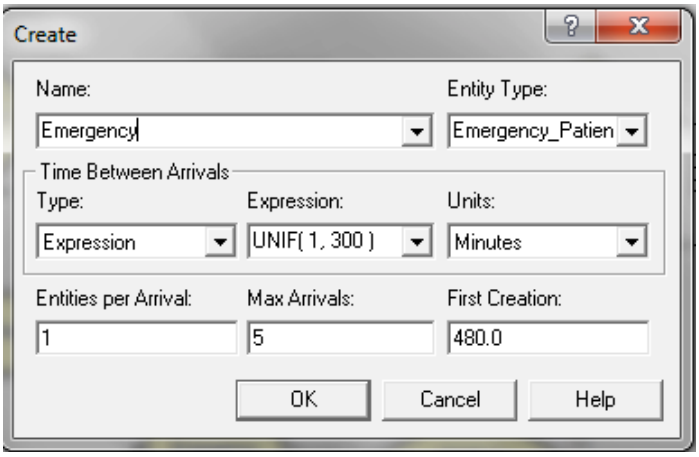

Figure 19: Emergency schedule of patients in the model ARENA

The interval between patient arrivals is given by uniform distribution UNIF (1, 300) minutes. Based on the suggestion from the clinic management nearly 4-5 arrivals on daily basis, hence the number five is at the upper bound.

b. Resources

Five main resources have been identified in the dental clinic namely – receptionists at the front desk, treatment rooms, dentists, dental assistants and cleaning crew. The list of resources used in the model is shown in Figure 20.

Resource - Basic Process

	Name	Type	Capacity
1	MSA1	Fixed Capacity	1
2	MSA2	Fixed Capacity	1
3	Chairs	Fixed Capacity	18
4	Hyg Room 1	Fixed Capacity	1
5	Hyg Room 2	Fixed Capacity	1
6	Hyg Room 3	Fixed Capacity	1
7	Gen.Chair 1a	Fixed Capacity	1
8	Gen.Chair 1b	Fixed Capacity	1
9	Gen.Chair 2	Fixed Capacity	1
10	Gen.Chair 3	Fixed Capacity	1
11	Gen.Chair 4	Fixed Capacity	1
12	Gen.Chair 5	Fixed Capacity	1
13	Gen.Chair 6	Fixed Capacity	1
14	Gen.Chair 7	Fixed Capacity	1
15	Gen.Chair 8	Fixed Capacity	1
16	Oral.Chair 1a	Fixed Capacity	1
17	Oral.Chair 1b	Fixed Capacity	1
18	Hyg 1	Fixed Capacity	1
19	Hyg 2	Fixed Capacity	1
20	Hyg 3	Fixed Capacity	1
21	Oral1	Fixed Capacity	1
22	Oral.Fellow1	Fixed Capacity	1
23	Oral.Fellow2	Fixed Capacity	1
24	Oral.Resident	Fixed Capacity	1
25	Gen.Chair1	Fixed Capacity	1

Set - Basic Process

	Name	Type	Members
1	Hyg Chairs	Resource	3 rows
2	MSA	Resource	2 rows
3	General Dentist Chairs	Resource	12 rows
4	Oral Surgery Chairs	Resource	5 rows
5	Hygienists	Resource	3 rows
6	Dentist	Resource	8 rows
7	Oral Surgeon	Resource	4 rows
8	Assistant	Resource	10 rows
9	Oral Assistant	Resource	5 rows

Figure 20: Resources in the clinic as modeled in ARENA

The resources are grouped using the SET module. The number of resources in each category is given in the member's column of the SET command. The grouping of resources is done to maximize the utilization and to evenly distribute the work. The choice of usage of resources is determined by various selection procedures like cyclical, smallest number busy, preferred order etc, as shown in figure 21. Based on the priority and resource availability, the module allows one to assign a particular resource to the specified task. For example, the clinic has a team of 3 (2 dentists and 1 dental assistant) exclusively in charge of emergency cases. As emergencies cannot be predicted in advance, the frequency of walk-ins remains undetermined. To increase the clinic utilization, the same crew works with the teams working on non-emergency cases as well. However, while working on other cases, if an emergency case arrives, the particular crew is re-assigned to take care of the emergency.

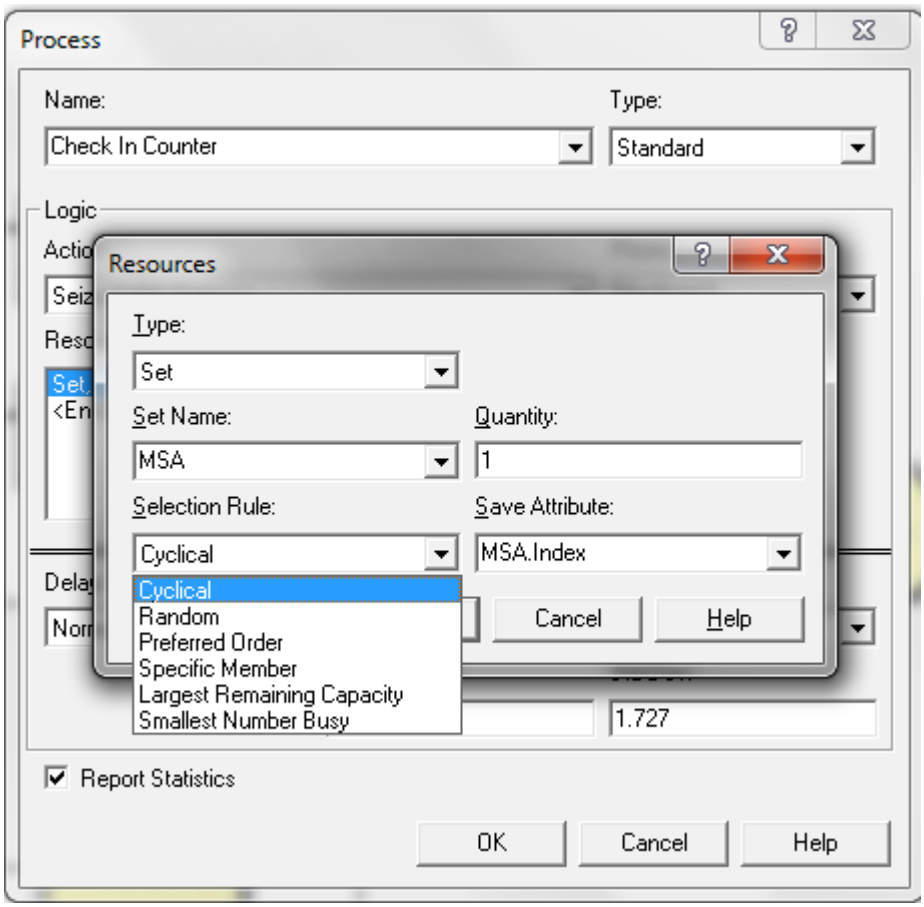

Figure 21: Selection rule of resources as modeled in ARENA

c. Process

The treatment at the clinic includes processes, which are simulated in the model. Checking in at the front desk, consultation with dentists and prepping the room for next appointment are the value added processes spent by the patient. The simulation details of the various processes are explained below.

a) Check In Process

Patients arrive at the clinic and check-in at the front desk. Majority of patients have a scheduled appointment to see their practitioner. Those individuals without an appointment inquire at the front desk about an appointment time. After check-in, patients will wait in the waiting room until a medical assistant calls their name. Based on the data

collected from the register at the front desk, the check in process follows a normal distribution.

It takes NORM (1.3265, 1.7247) minutes on an average to finish registering at the counter. New patients take longer times to complete the registration compared to follow-up patients. However, with the data collected it wasn't possible to distinguish the difference in the time taken at the registration desk between new and follow-up patients. Figure 22 gives the probability density distribution of the check-in times encountered at the front desk.

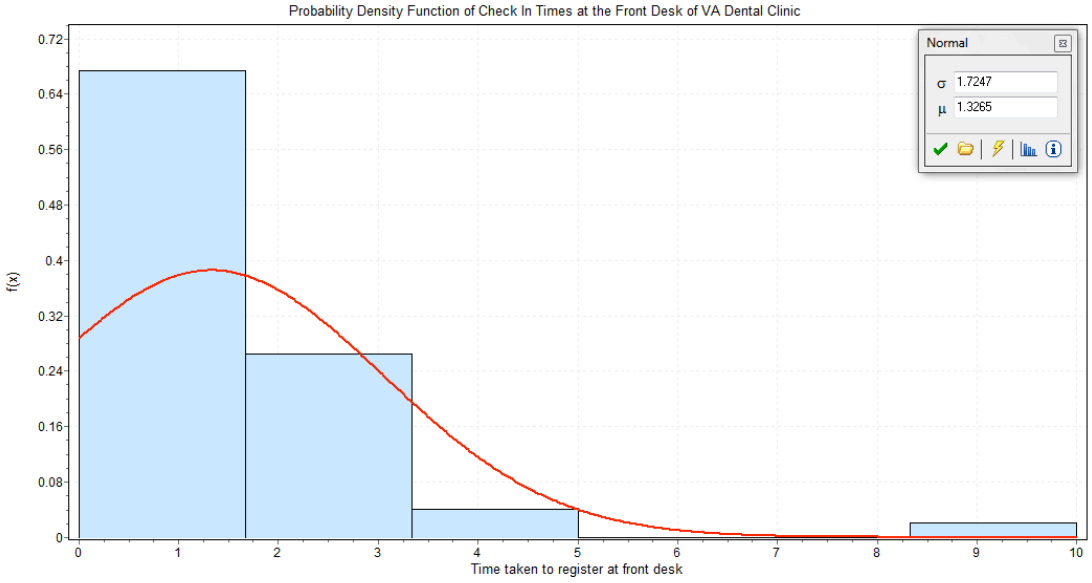

Figure 22: Probability density function of Check-in times at the VA Dental clinic

b) Consultation time

Consultation or service time is defined as the time during which a patient claims a doctor's attention, or at least prevents him from seeing the next patient (Bailey, 1952). The consultation time of the patients at the VA clinic varied based on the type of appointments. The 30-minute appointments were found to follow a distribution given by NORM (29.043, 8.83) minutes. Figure 23 and 24 give the probability distribution and P-P plots respectively, of the consultation times of 30-minute appointments

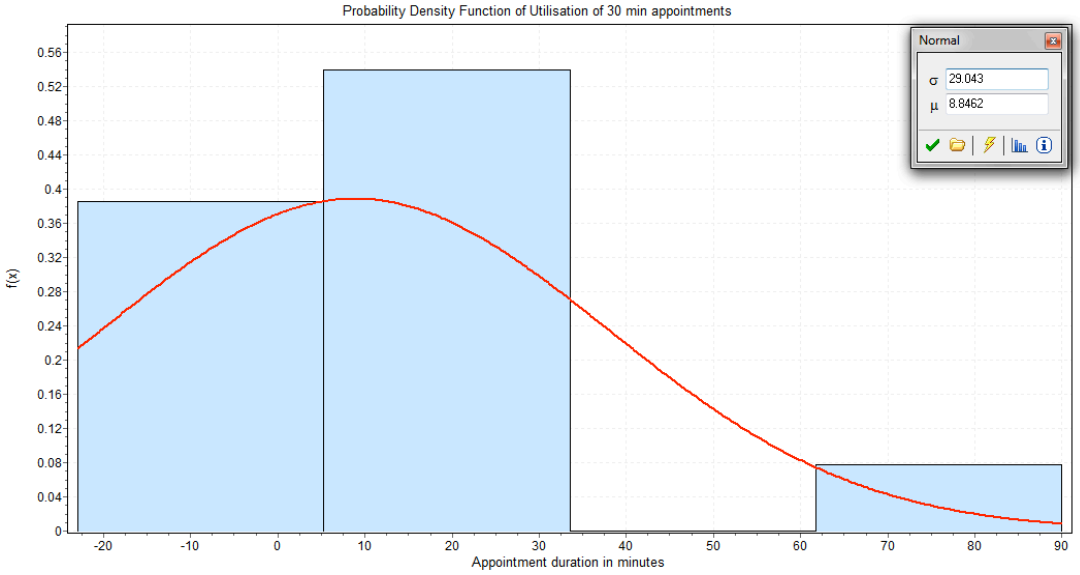

Figure 23: Probability distribution of consultation times of 30-minute appointments

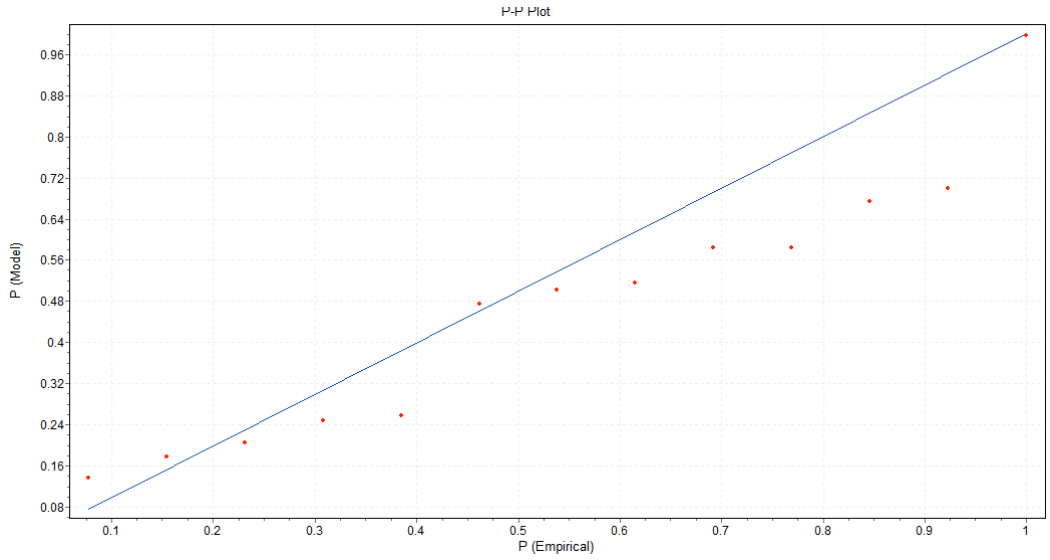

Figure 24: P-P plots of consultation times of 30-minute appointments

The 60-minute appointments were also found to follow normal distribution and the variation of the process times is given by the expression - NORM (54.032, 22.079) minutes. The probability density plots and the P-P plots for the 60-minute appointments are shown in figures 25 and 26 respectively.

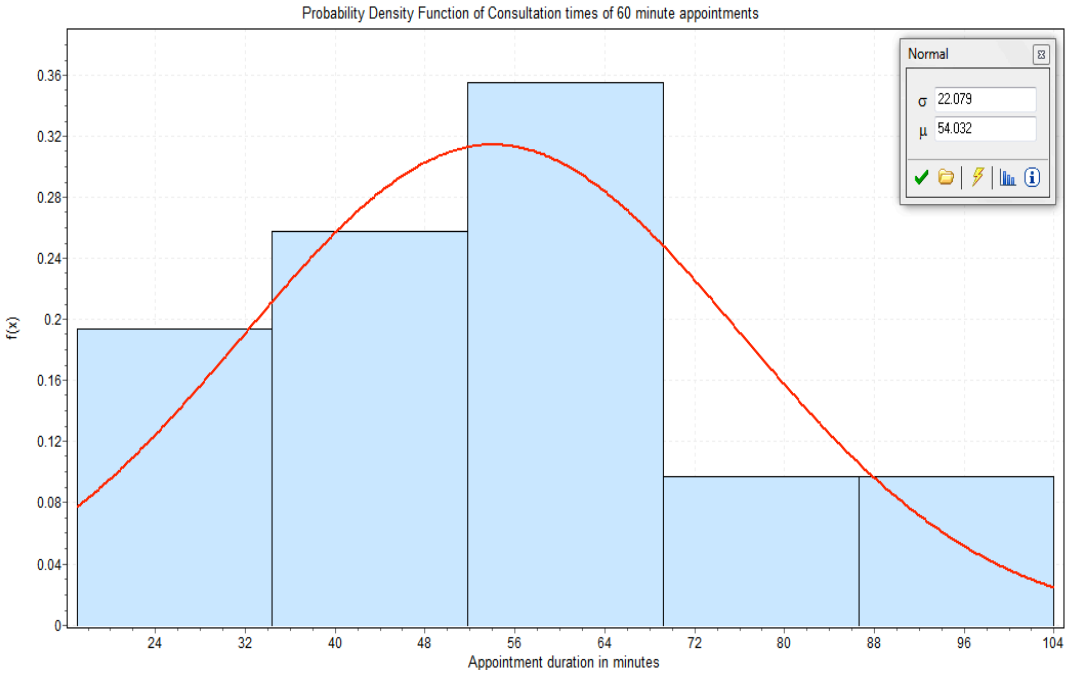

Figure 25: Probability density function of consultation times of 60 minute appointments

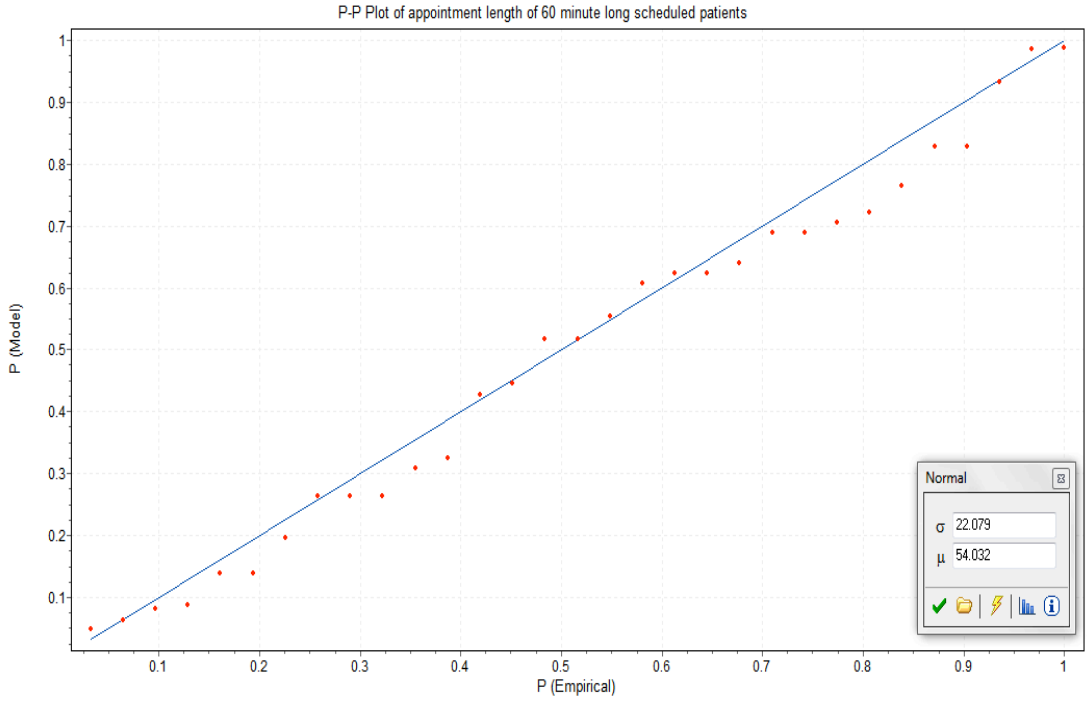

Figure 26: P-P plots of consultation times of the 60 minute appointments

The data collected didn't give much information on the other types of appointments namely 90-minute appointments, 120-minute appointments and emergency walk-ins. As the data was insufficient it wasn't possible to find any particular distributions to represent this type of appointments. However, the fact that the frequency of these appointments is very less compared to that of 30-minute and 60-minute appointments, these types of appointments don't seem to make any significant effect on the resource utilization of the dental clinic. The consult times of these appointments can be represented by uniform distribution and are given by

UNIF (85, 95) for 90-minute appointments,

UNIF (110-120) for 120-minute appointment and 60 minutes for all the walk-in appointments.

c) Cleaning Time

After the consultation, the patient exits the exam room, checks out at the front desk and leaves the clinic. Cleaning of room and prepping for the next appointment takes

POIS (6.2) minutes.

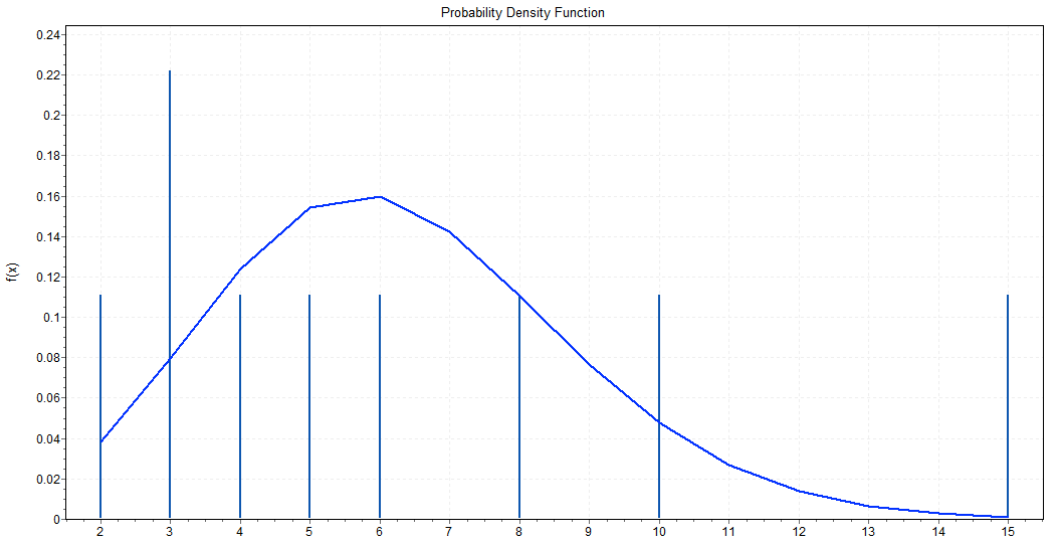

Figure 27: Probability density function of cleaning times of rooms in the model

d. Queues

There are delays experienced by patients in the clinic at various junctures. The process at the clinic starts with registration at the front desk. Depending on the time of appointment, patients might have to spend some time in the queue before checking in. The model uses first-in first-out queuing discipline model based on the patient's arrival time for the scheduled appointment. For a particular appointment time, patients are treated in the order of their arrival. Emergency patients are given the highest priority across the clinic.

The consultation process includes seizing a dental assistant, chair/room for treatment procedure and the dentist. After registration, patients wait near the front desk until a treatment room is allocated by the dental assistant. After a patient exits the treatment room, it takes a while to clean and prepare the room for the next consultation.

For the ease of understanding the clinic processes and the subsequent queue formations, the dental services at the VA clinic are divided into 4 groups. The resources available for each group as mentioned in the previous section are exclusive to the respective groups.

- General dentistry – Treatments in general dentistry include fluoride treatments, examinations, radiographs and so on. The clinic also brings in specialists in various fields like endodontics (root canal therapy, fillings, and crowns), periodontics (treatment of gingivitis and periodontal disease), prosthodontics (teeth whitening, dental implants, cosmetic dentistry, treating congenital and developmental mouth defects) who are available on temporary basis. As only one specialty is available per day, these procedures are clubbed with general dentistry.

- Oral dentistry – Oral surgery forms a different group due to the specific resources used for it. The chairs and rooms used for the oral procedures are specially equipped and cannot be substituted with other resources.

- Dental hygiene - Dental Hygiene includes procedures like regular cleaning, yearly follow-up of general dental care, teaching and providing instructions for proper oral hygiene and care.

- Emergency/Walk-ins

Figure 28 represents the various queues the patients might have to encounter during their course of the clinic visit.

Queue - Basic Process

	Name	Type
1	Check In Counter.Queue	First In First Out
2	Emergency Walkins.Queue	First In First Out
3	Procedures related to Oral dentistry.Queue	First In First Out
4	Procedures related to General Dentistry.Queue	First In First Out
5	Dental Hygiene Procedures.Queue	First In First Out
6	Seize Room for Emergency Patients.Queue	First In First Out
7	Seize room for patients with Oral Procedures.Queue	First In First Out
8	Seize room for patients with Gen Dentistry	First In First Out
9	Seize room for Dental Hygiene procedures.Queue	First In First Out

Figure 28: Queues in the model

5.4 Model Verification and Validation

Model verification and validation is an important part of model development. Verification confirms if the simulation program runs as per the designed process flow and validation checks if the model resembles the system under consideration. The model was trained and tested before being used for the final simulation. Each model is replicated 100 times to avoid any possible bias in the predicted results. Trace option has been used in ARENA to verify every step in a run performed by the model.

The simulation model is developed based on the data collected at the VA dental clinic. An animation of the model has been demonstrated to the hospital management to verify the flow process, output results and applicability of the model to the current clinic settings. Dr. Templeton and Dr. Lou confirmed that the model's flow is a good

representation of the major processes of the outpatient clinic. The model is hence valid and could be used for testing new configurations/possible modifications to the clinic.

The model exactly replicates the real time scenario of the VA clinic. For verification and validation of the model, the behaviors of different types of patients were followed through the system. The first patient arrives at the clinic at 7:30am and the interval between patient arrivals follows a distribution which is fed into the model. No patients are treated during the lunch break (12 noon to 1pm) as is the case with the real system. The model is simulated in such a way that no appointments are scheduled after 4 pm. However the model terminates only after 5pm or after treating all the patients who are scheduled for appointments before 4pm. The scheduling of dentists, dental assistants, cleaning crew, front desk receptionists and treatment rooms follows the same pattern as the clinic.

Validation involves comparing the model's output with the real system. The length of the simulation run is 1440 minutes (24 hours). Total number of patient appointments in a day, number of patients treated or consulted based on their appointment types, mean treatment/consultation time are the parameters used for validation. Clinic closing time, resource utilization (dentist, receptionist, dental assistant), patient waiting times were also compared to validate the simulation model.

From the simulation, the average number of patients treated in the model is obtained as 71 which is an accurate estimation based on the number of patients treated in the VA clinic as shown in figure 4. The model was also validated against the number of patient consultations based on the type of appointments (30min, 60min, 90min, 120 min and emergency walk-ins). The simulation results compared to real time statistics are given in table 6 along with the percentage errors. The errors are not tabulated in cases where the sample size is statistically insignificant ($N<10$).

	Number of patients seen			Mean Consultation time		
	Actual	Simulation	Error (%)	Actual	Simulation	Error (%)
30 min	13	15	15	42	42	0
60 min	31	39	25.8	54	54	0
90 min	1	1	N/A	87	71	N/A
120 min	1	1	N/A	110	104	N/A
Emergency	3	3	N/A	54	83	N/A

Table 5: Comparison of simulation results to actual data- Average number of patients seen on daily basis

The simulation model over predicts the number of patients seen compared to the data collected. The error in the difference of patients seen on a daily basis can be attributed to the fact that the data was collected over a span of 3 days while in the model; the data is averaged over 100 simulations. The variability may also be because of the model cannot capture the real life situations happening at the closing hours. In the VA clinic, patients might be asked to come on a different day based on the current queue and the estimated length of the consultation time. The model cannot predict such scenarios. Nevertheless, the average time taken for a consultation is a very strong indicator that the model captures the real time scenario in the VA clinic (as shown in figure 29).

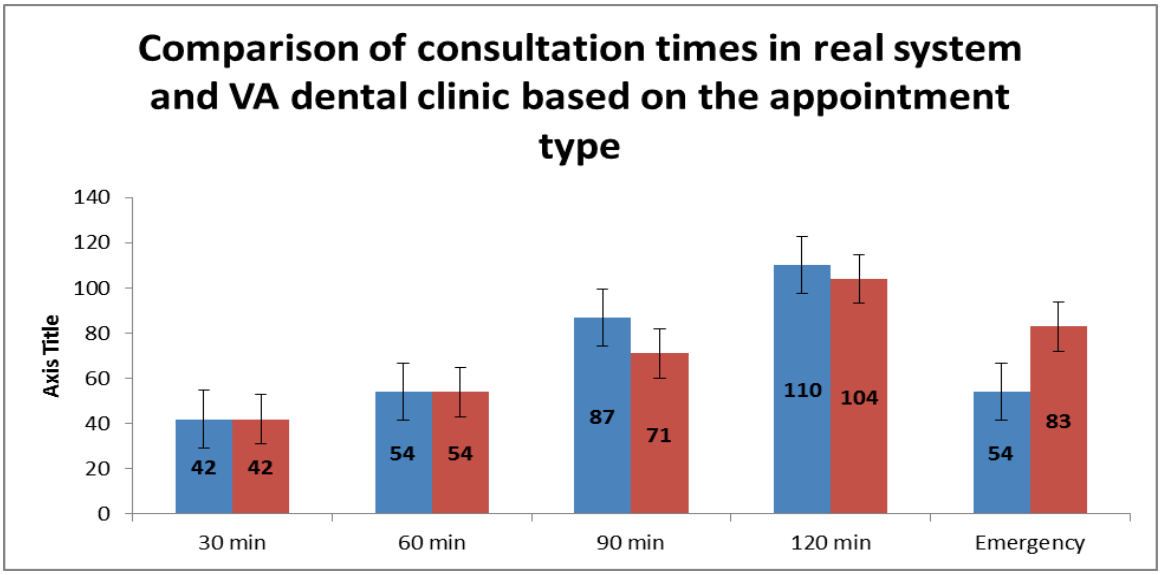

Figure 29: Comparison of consultation times of real time with simulation data based on appointment type

The model is now used to simulate the scenario for three different appointment configurations suggested for the better utilization of facilities. The following section discusses in detail the appointment system while the simulation results are discussed in the next chapter.

5.5 Modifications to the simulation model

Based on the modifications suggested to the appointment system in section 2.5, the following changes are made to the basic simulation model. The details of the changes made to the model are given below.

I. Reducing the number of appointment types

In the first scenario, the model has been reduced to only two appointment types - 60 and 120 minute, while the second scenario deals with appointment types 30 and 60 minute appointment lengths.

a. 60 and 120 minute appointment slots

This configuration has only two appointment types (60 minutes and 120 minutes) as against the basic model which has four different appointment types.

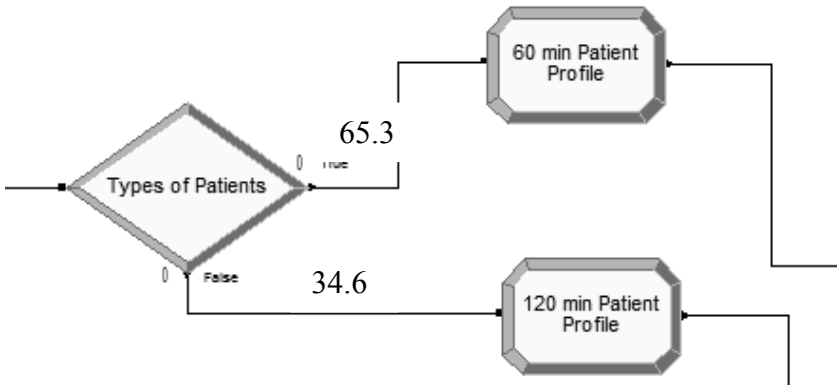

Figure 30: Percentage distribution of patients based on appointment length in configuration #1

The input parameters for this configuration were based on the consultation times taken for the patients as per the data collected. All the cases where the consultation time

was less than 60 minutes were grouped under the 60-minute appointment type and the rest were grouped under the 120-minute appointment type. The percentage distribution of 60-minute appointments is higher than that of 120-minute appointments and accounts for more than sixty-five percent of the total observations.

The mean consultation time of the 32 observations ranging between 0 and 60 minutes is 38.5 minutes with standard deviation of 14 minutes. 17 of the 49 observations had their consultation time extend over 60 minutes and have mean and standard deviation of 84 and 26 minutes respectively.

The beta distributions,

5.6 + 59 * BETA (1.3792, 0.95995) - (60 minute appointment),

62.5 + 157 * BETA (0.34386, 1.2751) - (120 minute appointment)

represent the respective consultation times. The probability density function and the P-P plots of both the distributions are as shown in figure 31.

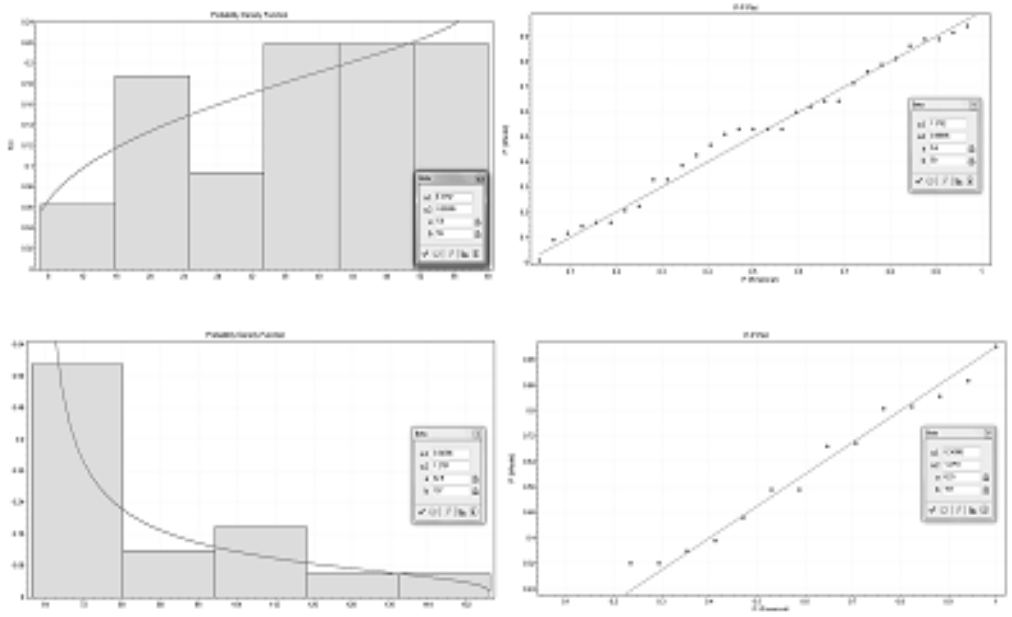

Figure 31: Probability density and P-P plots of 60 min and 120 min appointments as modeled in appointment configuration #1

b. 30 minute and 60 minute appointment slots

Along similar lines with the first configuration it is attempted to see the effect of only 30 minute and 60 minute appointment types. From the data collected, the number of 90 minutes and 120 minute appointment are statistically insignificant compared to the other two appointment types and hence are neglected in this configuration.

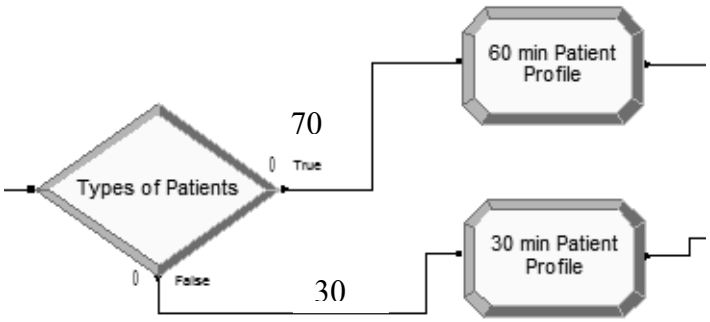

Figure 32: Percentage distribution of patients based on appointment length in configuration #2

The total number of 30-minute appointments after neglecting the 90 and 120 minute appointments is thirty percent of the total observations. The mean and the standard deviation of the 30-minute consultation times are 42 and 27.96 minutes respectively. The consultation process is represented by the gamma distribution

GAMM (18.793, 2.2144) - (30 minute appointment type)

Majority of the appointments in the clinic are 60 minute appointments and any improvement in this type of appointments would drastically affect the overall working of the clinic. The mean of the 60 minute consultations is 58.3 minutes and the standard deviation is 28.8 minutes respectively. The consultation time is represented in the model by weibull distribution given as,

WEIB (63.467, 2.44) - (60 minute appointment type)

The probability density function and the P-P plots of the 30 and 60 minute appointment type is given in figure 33.

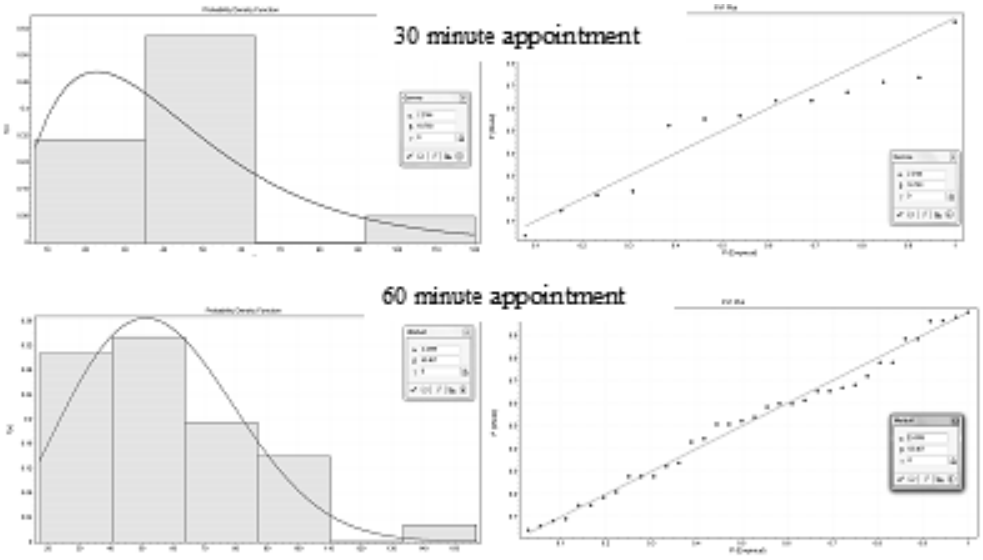

Figure 33: Probability density and P-P plots of 30 min and 60 min appointments as modeled in appointment configuration #2

II. Pooled v/s Individual doctor assignment

Modeling the system based on this suggestion is not feasible to be done for the whole clinic. This suggestion is incorporated to see the effect only on hygienists. A sub model has been created for only the hygienists; comparing the effect when treating them as individuals as against a set for giving appointments.

The model run length is only for 8 hours as compared to other specialties, hygienists close early by one hour. The number of patients visiting the hygienist is less variable and is given by uniform distribution. The time between arrivals is given by UNIF (30, 50) minutes and 3 patients enter per arrival. The model for the hygienists is depicted in figure 34, representing the individual and pooled set of dentists.

In the first scenario, appointments are given with specific hygienists. While in the second case, appointments are directed to the clinic and the allotment of hygienist (from a pool of three) happens at the time of appointment depending on the hygienist availability.

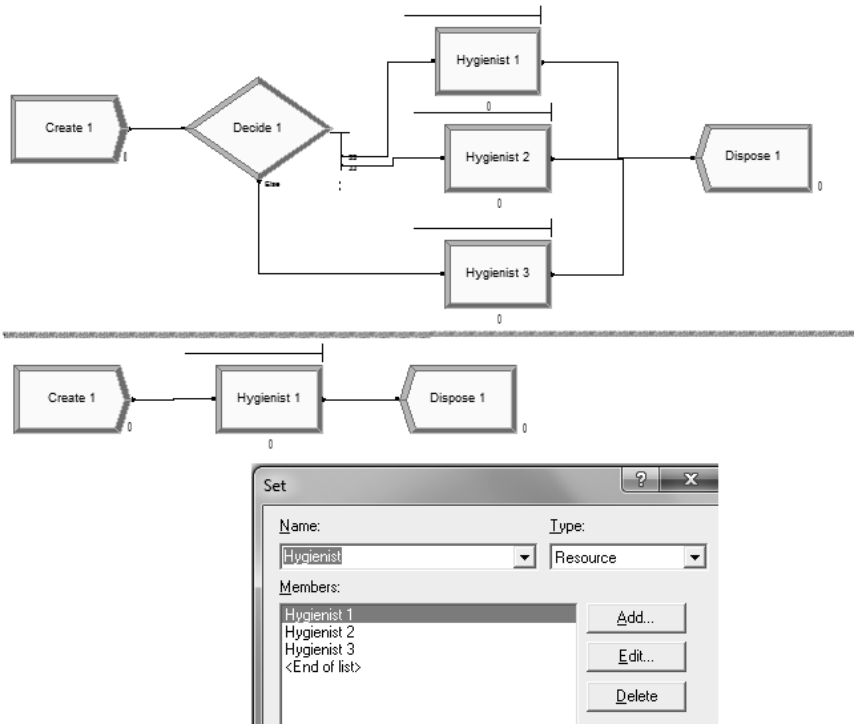

Figure 34: Sub model of dental clinic with only hygienists. Appointments based on individual appointments (above) appointments based on pooled resources (below)

The process times of the hygienist consultation is given by uniform distribution – UNIF (19.5, 82.5). The probability density function and the P-P plots of the hygienist process times are given below.

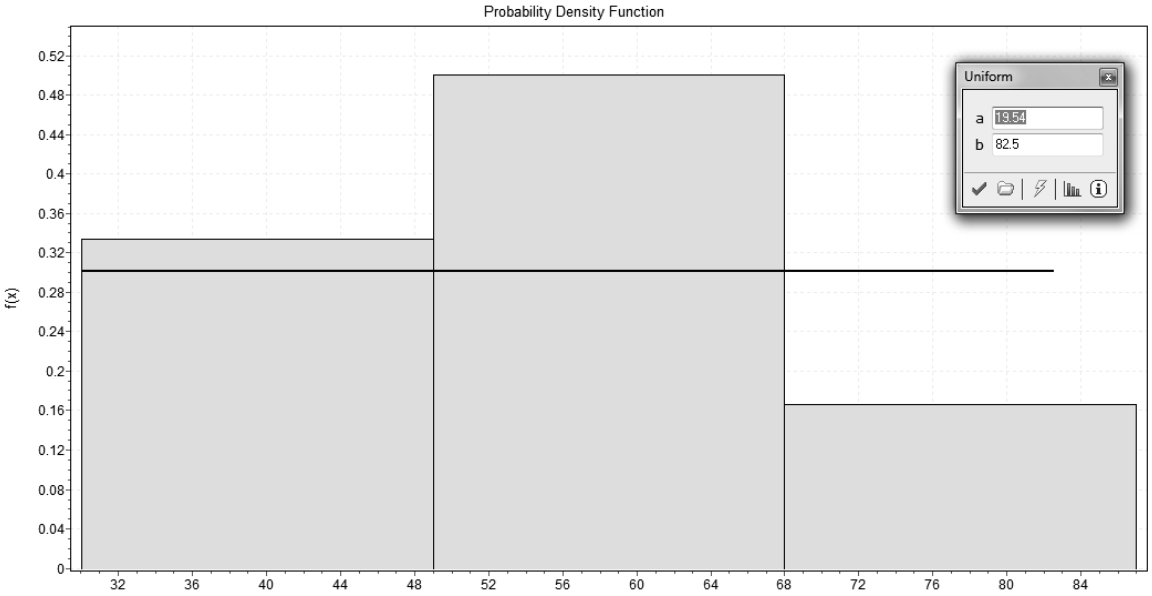

Figure 35: Probability density function of consultation times of Hygienists

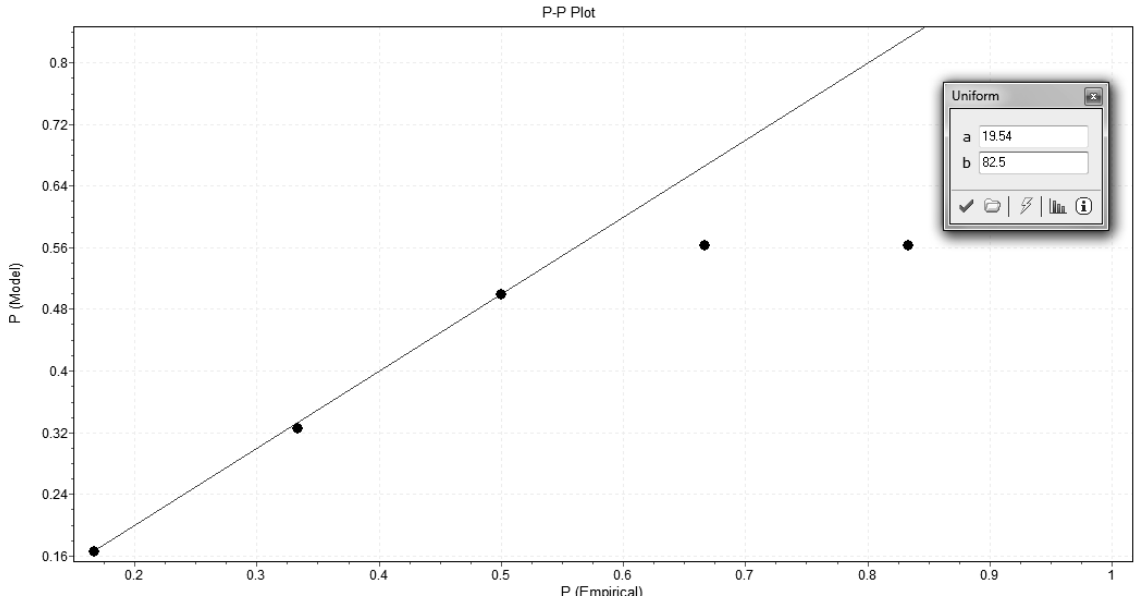

Figure 36: P-P plot of consultation times of hygienists

Results from the simulation and brief discussion on each are given in the next chapter.

Chapter 6

Results and discussion

The aim of this project is two-fold. The objectives of this study are to replicate the scheduling system currently in place at the VA dental clinic and to test the effect of the suggested appointment configurations. To evaluate the performance of the configuration, certain indicators need to be defined. In this thesis, the indicators can be calculated from the simulations. To compare the clinic sessions with different appointment types and allocation of hygienists, the following parameters are identified.

a. *Number of patients* - The number of patients seen on a daily basis is the standard performance indicator used by the clinic management to evaluate the clinic.

b. *Waiting time* – Access delays and internal waiting times are the two kind of delays patients experience during their time at the clinic for consultation. Access delays could not be estimated by the simulation. Hence only the direct waiting time during the appointment is calculated. Higher waiting times indicate that the processes are not streamlined and affect the patients' experience at the clinic in a negative way.

c. *Resource Utilization* – One of the objectives of this study is to improve the utilization of the resources used in the clinic. Utilization rates give the percentage of the total time the particular resource was in use. The resources included in the study are dentists, treatment rooms and clinic staff which include receptionists and dental assistants. This parameter also gives an indication of the idle times of the various resources.

d. *Clinic closing time* – The clinic closing hour is an important parameter used by clinic management in estimating the extra hours the staff had to put in to complete the tasks.

Time spent in the clinic by the patient can be divided into value added, non-value added and waiting times. Figure 37 gives the list of these times spent by the patients in the clinic based on the appointment types. In the current model, the consultation time is the only value added process. The time spent at the front desk and the time spent on preparing the room for the next appointment can be classified as the non-value added time.

The non-value added time is almost similar across the appointment types. However the waiting times are quite different from one another. The patients encounter longer waiting times with 60-minute appointment type. The 60-minute appointment patients are delayed by 31 minutes on an average, which is the maximum, and emergency care has zero waiting time. A closer look at the queues and process reflected that one of the main reasons for the higher waiting times in the 60-minute appointment type is the delay in finding a hygienist chair. All the hygienist's appointments are of 60-minute appointment length. As shown in table 5, hygienists and hygienist chairs have the maximum utilization of 76 and 84 percent respectively. But to seize a hygienist chair, the average time spent by the patients in the queue is 51 minutes. The other reason for the high waiting times for the 60 minute appointment type is the because fo the number of patients scheduled with this appointment type (63 percent of the total appointments are 60 minute appointment slots). Reducing the waiting times directly increases the productivity of the clinic and ensures better resource utilization.

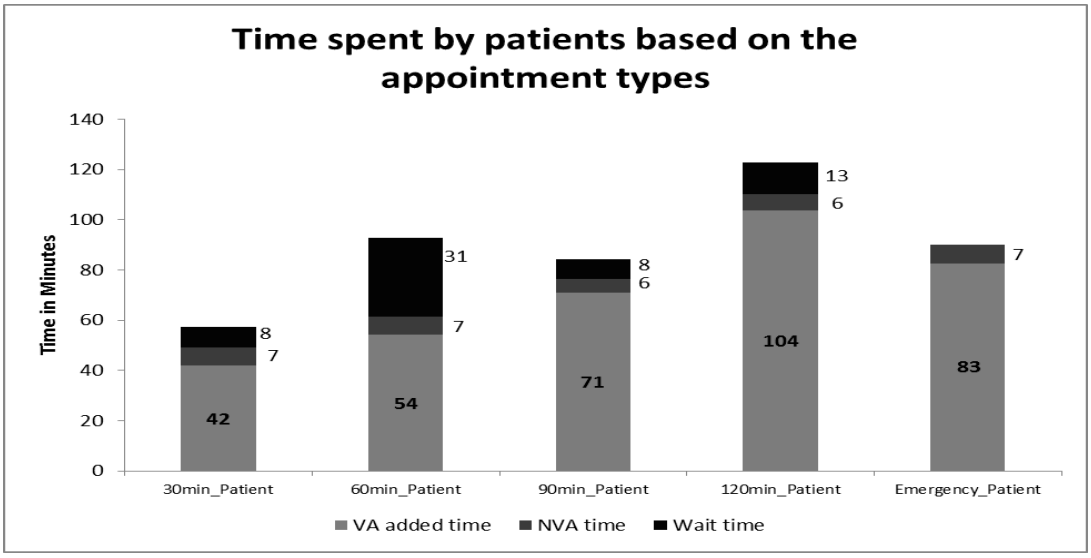

Figure 37: Time spent by patient at the clinic based on appointment types

The delay across various other dentistry chairs and process is given in figure 38. The patients had negligible waiting time at the front desk (not shown in the figure due to insignificant number compared to other parameters in the graph). The average accumulated delay at the checking-in process is 2.43 minutes over 100 replications. The average time taken to check in at the front desk is 1.3 minutes. Hygienists have the maximum waiting times of 51 minutes followed by the oral dentistry. An average of 10 minutes are spent by oral dentistry patients to obtain a treatment room There is a delay of 5 minutes in obtaining treatment room for emergency cases. However, no delay in treatment process in observed for the emergency walk-ins.

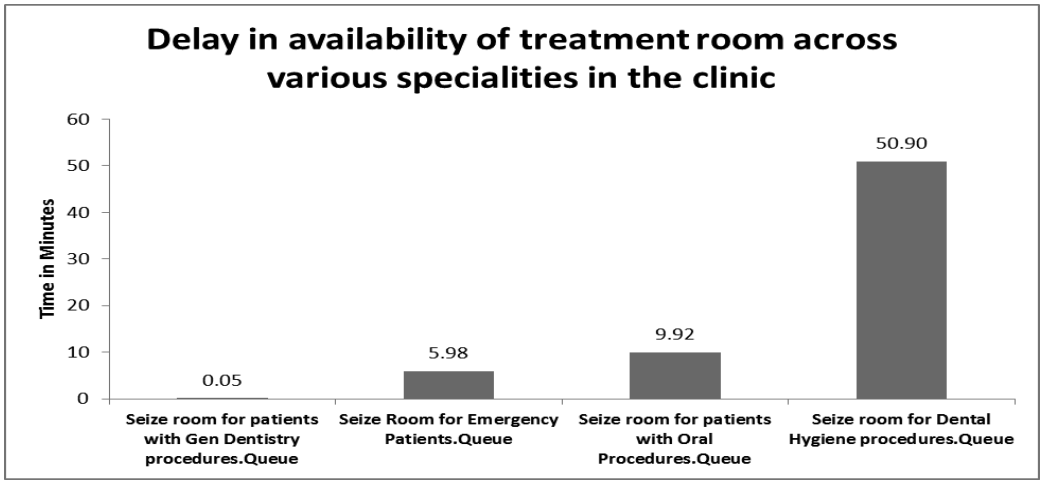

Figure 38: Delay in availability of treatment rooms across various specialties in the clinic

Table 6 gives the utilization of various resources used across the medical specialties in the clinic. Dental hygiene reports maximum utilization of both the hygienists and the treatment rooms compared to other specialties. The team of three hygienists treats 20 patients on a daily basis. The oral dentistry treats 18 patients on an average per day, but the utilization rates of the resources used in this department are far less compared to dental hygiene. General dentistry with 7 dentists, 11 treatment chairs and 9 dental assistants has the least utilization of resources among the four groups. The low waiting delays observed for the patients getting treated in the oral and general dentistry procedures is because of the low number of patients.

Specialty	Oral		General		Dental Hygiene		Emergency	
Resource	Number	Utilization (%)	Number	Utilization (%)	Number	Utilization (%)	Number	Utilization (%)
Dentist	4	56	7	31	3	76	1	67
Treatment room/ Chair	5	53	11	22	3	83.7	1	61
Dental Assistant	5	45	9	24	0	0	1	67

Table 6: Utilization of various resources across various specialties at VA dental clinic

The clinic closing hours are recorded from the 100 replications. The average closing time is from the simulations is 1140 minutes which is at 7:00 pm. The clinic is

scheduled to close at 5:00pm. Hence the extra two hours of patient delays can be reduced if the waiting times are reduced.

The low utilization of resources suggests that the clinic is not working to its capacity and more patients can be accommodated for treatment with the same resources. It should also be noted that these utilization rates cannot be taken as the overall utilization of the resources. Dentists and clinic staff participate in several other activities apart from the consultation which are not included in the table above. Apart from consultation, dentists are involved in various administrative tasks such as meetings, report preparation, training and seminars, reviewing patient cases and researching about new medical issues. However, keeping in view all the facts the utilization of the resources can be improved in the clinic.

I. Reducing number of appointment types

The simulation results of the first 2 appointment configurations which focus on reducing the number of appointment types are discussed in this section. The model designed as per section 4.5 was run for 100 replications. The results are compared to the original simulation model. It has been observed that the total number of patients seen by the clinic in all the 3 models – original simulation, 60-120 minute appointment configuration and 30-60 minute appointment configuration is almost similar with the number of patients increasing by 5 in the latter two cases.

Comparison of waiting times and utilization of resources for various processes included during the patient visits at the VA clinic are given in figure 39 and 40 respectively. It is clearly seen that the waiting times of dental hygiene procedures reduced by more than 50 percent. However the waiting times of emergency care and oral procedures increased in 60-120 minute appointment configuration model compared to the existing model. In case of 30-60 minute appointment configurations, the waiting time of dental hygiene procedures and emergency care increased with respect to the original model, but there is an decrease of about 84 percent in the waiting times at the oral procedures.

This irregular increase/decrease of waiting times across the procedures can be interpreted this way - Dental hygiene procedures on an industry average take nearly 60 minutes long or higher. Due to the high variability of consultation times of 60 minute appointment in the existing model, the waiting times are 51 minutes. In the 60-120 and 30-60 minute appointment configurations, the consultation times are almost similar but there lies difference in the number of patients seen. The original and the 30-60 minute appointment configurations see 20/21 patients on an average on daily basis compared to only 19 patients in the 60-120 appointment configuration. Though the difference in the number of patients is minimal, the average waiting time per person in the models are 51, 23 and 73 minutes for the original, 60-120, 30-60 minute configurations. Hence the decrease of waiting time is understood. The only way to reduce the long waiting delays for the hygienist procedures are by increasing the resources allocated to the department.

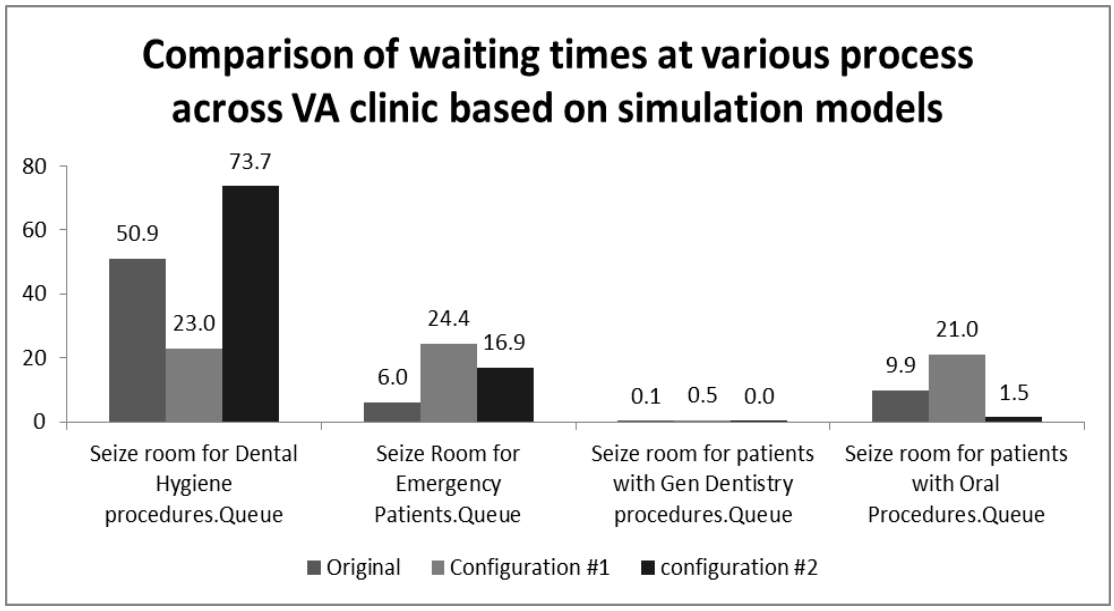

Figure 39: Comparison of waiting times of resources across VA dental clinic based on the simulation models

The waiting times of the emergency care increased in the 60-120 and 30-60 appointment configurations. This is because of the way the emergency resources are utilized and the number of patients treated per day. 30-60 minute appointment configuration treated 3 emergency patients while the average number of patients treated in 60-120 appointment

configuration is 4 compared to only 2 emergency patients in the original model. Hence the increase in waiting times is a scheduling based error in the randomizing the patient populations and does not reflect on the clinic. Another reason for the higher waiting times is the small sample size of the emergency walk-ins. The general dentistry has the least waiting times compared to other specialties. The waiting times of oral procedures decreased in the 30-60 minute configuration due to difference in the number of patients treated.

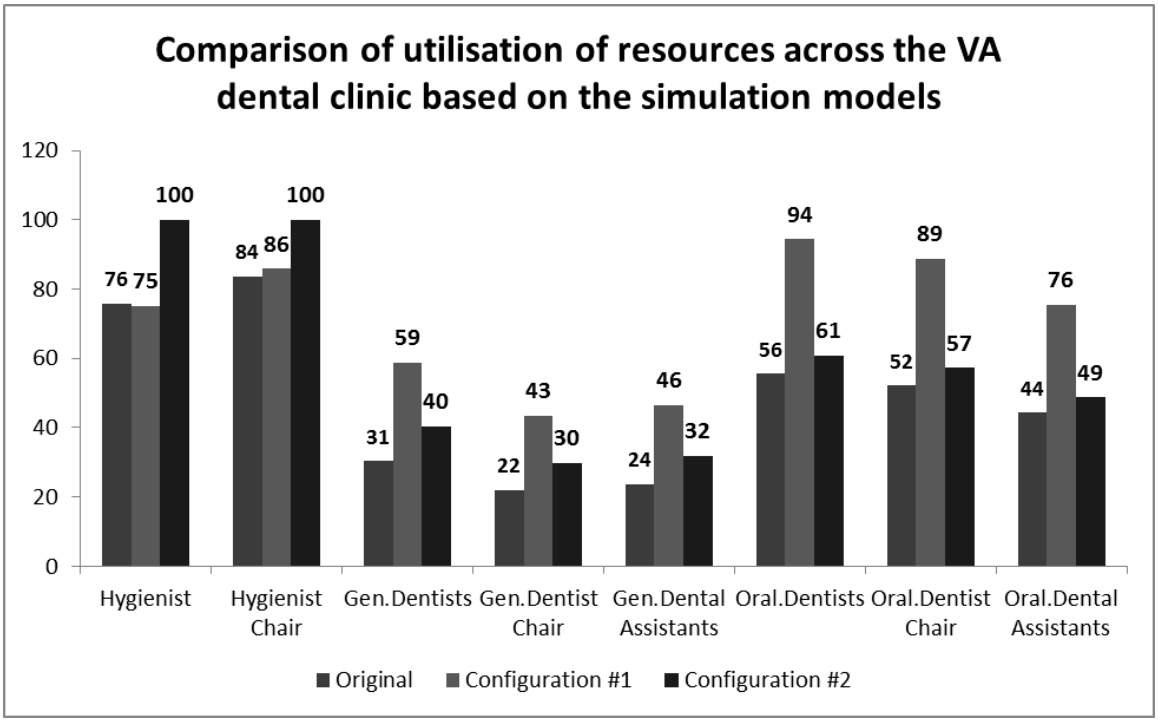

Figure 40: Comparison of utilization of resources across VA dental clinic based on the simulation models

The utilization of resources across the VA clinic specialties can be seen below. It is evident that the percent utilization of hygienists and hygienist chairs is maximum in the case of configuration 2 compared to other models. The difference in the utilization is based on the number of patients treated. The increase in the utilization rates of the general dentistry and oral dentistry procedures are not because of the increase in patients seen but because of the longer consultation hours. Few of the general dentist appointments include follow-up check-ups which last for a maximum of 20-30 minutes. But with only 60 and

120 minute appointments in place, the average consultation time increased and subsequently the utilization of resources. The utilization of such appointment lengths with the actual consultations can be verified only by the clinic management. Though there is a significant increase/decrease of the utilization/waiting times for the process, no conclusion can be drawn on the overall effectiveness of the new appointment configurations.

II. Pooled v/s individual hygienists

A comparison was made for the number of patients treated and the average waiting time of the patients between the two configurations. As mentioned before, there are 3 hygienists currently working in the VA clinic and the model used the same number.

The model predicts that on an average the number of patients seen per day by the hygienists increased from 21 to 24 patients. There is an increase of 3 patients per day and a patient more per hygienist on an average per day. A significant decrease of waiting time is also observed on changing the allocation of appointments from individual hygienists to pool of hygienists. Compared to 41 minutes in individual appointment system, patients wait about 11 minutes in the pool system.

The percentage utilization of the hygienists showed a remarkable improvement of 13% on bringing about this change to the model. The numbers obtained from the simulations are compared in the figure 41.

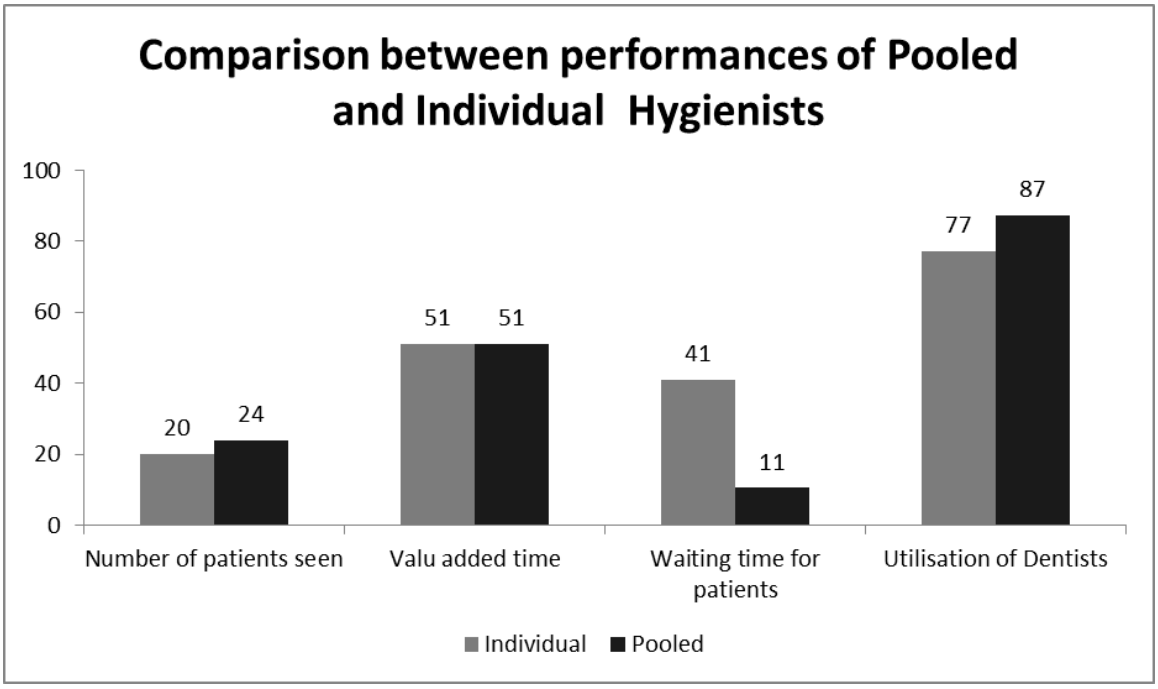

Figure 41: Comparison between performances of pooled and hygienists

From the figure, it is pretty evident that the numbers are better when the hygienists are pooled as against giving appointments to individual hygienists. This can very well be extended to other domains across the entire clinic which would bring about remarkable improvements on the resource utilization of the clinic.

Chapter 7

Conclusions & Future work

6.1 Conclusions

The simulation model of the outpatient dental clinic shows that a number of changes in the appointment system can result in significant improvements in average access times, average internal waiting times, overtime, and utilization. The model was validated with the data collected from the VA clinic and the comparison showed that the model closely represents the real time scenario at the clinic. Based on the model, data collected from the clinic and discussion with the clinic management three different improvements to the existing model have been suggested and simulated to check for possible improvements.

The main results from the simulations on incorporating the suggested changes can be summarized as follows

a. The tradeoff among number of patients seen, resource utilization, waiting time and clinic close time could not be completely assessed based only on reducing appointment types. The resource utilization and the number of patients seen increased due to less variability in patient consultations but the waiting times increased. Clinic management should be carefully estimate the

b. Simulations were carried out to see the effect of pooling the hygienists as against giving appointments with individual hygienists. The results suggest that remarkable improvement in the resource utilization is possible by implementing the idea. Certainly, this looks like a promising change that can be implemented and extended to other specialties of the dental clinic as well.

Based on the simulations and the study, the following recommendations could be implemented to improve the overall performance of the clinic.

6.2 Recommendations

The following recommendations are suggested to the management and dentists of VA Dental clinic on the basis of the simulations as part of the undertaken study.

- *Standardization of Procedures* – The dental clinic has a high variability of consultation times even for common procedures like cleaning of teeth. The difference in the performance of doing similar tasks is seen across the clinic. This could be reduced by employing standard procedures for the same functionality. With standard procedures in place, deciding the appropriate appointment types becomes an easy task.

- *Patient no-shows* - There is no specific policy determining the rules of patient no-shows. Unless there is a deterrent, such behavior can be habitual. If a patient doesn't show up for the appointment, it adds to the clinic costs and wastage of resources. Imposing fines is one obvious way to reduce the problem. As the current clinic is a government funded organization, the patients/veterans do not actually pay for their visits. Hence other ways of imposing restrictions should be thought about.

- *Appointment late arrivals* - For late shows, the clinic should have clear policies as to how much delay is permissible before cancelling the appointment. Few private clinics expect the patients to arrive at least 15 minutes before the appointment time. Patients arriving up to 15 minutes after the scheduled start of appointment are accepted. Any patient arriving before the rescheduling deadline should be allowed to check in only at the convenience of other patients; no other patient should be delayed because of the late patient's tardiness.

- *Appointment cancellations* - A 24 hour notice period should be made minimal for successful cancellation of appointment. Scheduling other patients for the cancelled appointment and informing patient and care provider becomes a herculean task when the notice period remains short. A record of the patient activity should be available to

receptionists and future appointments should be based on the punctuality record of the patients.

- *Reminder System* - To reduce the patient no-shows and cancellations, reminder system should be introduced. Reminders should be sent to patients via phone, mail or message regarding their appointment. Reminders can be sent by automated mail delivery systems instead of assigning it to receptionists or hiring new personnel. Numerous softwares that have this functionality are available in the market.

    - For the follow up appointments, collaboration between care providers and receptionist is important in optimal utilization of appointments. If care providers can estimate the approximate time for the follow-up, receptionist can feed the data in the system and schedule an appropriate appointment time which would otherwise normally result in the underutilization of the appointment time.

    - The current software used by the clinic should be upgraded and special teaching sessions be made so that all the workforce are acquainted with the system

    - We recommend repeating time measurements and management information analyses on a regular basis to monitor the appointment-system performance. The averages and variances of the consultation types can be adjusted according to recent time measurements, resulting in better estimates of consultation durations. A changing percentage of new patients and employing a new doctor are other reasons to perform time measurements again.

    - One issue faced by the clinic in optimizing utilization is the division of work. The clinic can think of achievable goals and give incentives to those dentists who show extra enthusiasm.

- One observation made by the Clinic Head is the lateness of arrival of dentists. This lack of punctuality further delays the appointments leading to overwork. One way to reduce such happenings is to conduct early morning team meetings. Starting a day knowing the goals can create a nice vibe and make mornings more enthusiastic. Meetings with higher management will also ensure early arrival of dentists to the clinic.

- Conduct exclusive walk-in for certain amount of time on a daily basis. This may reduce the total number of

- Special weeks can be celebrated exclusively with few dental specialties to attract more patients and to reduce the waiting lists

- To reduce the anxiety of patients while waiting self-help books, magazines on dental hygiene, videos on flossing and oral health can be provided.

- To improve the work environment and reduce the stress of working, music can be an alternative. Playing personalized music at accepted decibels can improve the work environment of the clinic.

For effectively implementing these suggestions, advance notification, publication of rules, patient educations is needed. Receptionists can also brief the policies before scheduling, cancelling or rescheduling appointments.

6.3 Future Work

Based on the conclusions from the current study and the present scenario at the clinic, the following studies may be done in the future to further improve the effectiveness of the clinic.

- To improve the clinic performances, more resource might be needed in future. Having place for these in the clinic is another issue in sight. The

space optimization which is an important parameter was not considered part of this study. Hence along with time studies more focus should also be placed on space utilization.

- The observed consultation times ranged across 7 10 120 minutes. For shorter consultations, appointment slots of 15 minute increments should also be tested for further. Standard appointments of 15, 30, 45 and 60 minutes can also be another appointment configuration the clinic management would be interested in trying.

- The current study is limited by its scope and data set. More detailed analysis of process with larger data sets is recommended for future studies.

- Due to time constraints the clinic was studied and recommendations made. However the impact of these recommendations on the clinic processes is not measured and is suggested to the clinic management.

- Pooling of resources in other dental specialties should also be studied

The decision models successfully incorporated all relevant patient criteria without adversely affecting the clinic system. Future research is needed to better understand what factors will impact system measures and expand the decision models to other outpatient clinic settings.

Appendix

Definitions as per Veterans Health Administration

Dental Hygienist: Dental professional specializing in cleaning teeth and educating patients in proper oral hygiene.

Endodontics: The dental specialty concerned with the morphology, physiology and pathology of the dental pulp and associated tissues.

Full-Time Equivalent (FTE): A staffing parameter equal to the amount of time assigned to one full time employee. It may be composed of several part-time employees whose total time commitment equals that of a full-time employee. One FTE equals a 40 hours per week.

General Practice Dental Resident (1 yr, 2 yr): A dentist participating in an accredited post-doctoral dental training program that provides experience in a comprehensive range of dental care. Residency programs may be 1 or 2 years in duration.

Oral Surgeon: A dentist who specializes in surgery of the mouth and removal of teeth.

Periodontics: The dental specialty that includes the prevention, diagnosis and treatment of diseases of the gums and supporting structures of the teeth, and the maintenance of the health of these tissues and structures

Care provider/Dentist: A medical professional trained in the evaluation, diagnosis, prevention and treatment of diseases and conditions of the teeth and associated oral structures

Prosthodontics: The dental specialty that involves the use of artificial replacements for missing or deficient teeth or oral and maxillo-facial tissues.

Current Staffing	
ENTER Current Chief FTEE	1.00
ENTER Current Dentist FTEE	7.20
ENTER Current Hygienist FTEE	2.00
ENTER Current Assistant FTEE	16.00
ENTER Current Resident FTEE	5.20
ENTER Current Dental Lab Technician FTEE	1.00
ENTER Current Administrative-Clerical FTEE	2.00
Current Treatment Space	
ENTER Current Treatment Rooms	18
Labor Mapping	
Chief Direct Patient Care Time	50%
Average Staff Dentist Direct Patient Care Time	88%
Average Hygienist Direct Patient Care Time	88%
Production Targets	
Modeled Staff RVU Target	125,000
Modeled Hygiene RVU Target	75,000
Staffing Ratios	
Modeled Assistant/Dentist Ratio	1.50
Modeled Assistant/Resident Ratio	1.00
Modeled Assistant/Hygienist Ratio	0.00
Percent of Workload Done by Hygienists	18%
Modeled Lab Tech/Dentist Ratio	0.30
Modeled Admin-Clerical/Patient Ratio	1200
Treatment Rooms	
Modeled Treatment Rooms per Dentist	2.00
Modeled Treatment Rooms per Resident	1.00
Modeled Treatment Rooms per Hygienist	1.00
Time Residents in Off Service Rotations	25%

Patient	Card No.	Appt Description / Treatment	Appt Time	Appt Duration (Hours)	Arrival Time	Check-in Time, Start	Time Seen by Dentist, Start	Check-out Time, Start
1	1	Extractions, Oral Surgery	9:30	1:00	9:13	9:14	9:45	10:52
2	2	Oral Surgery	10:30	0:30	9:18	9:18	10:05	10:24
3	3		10:00	1:00	9:21	9:22	10:03	11:00
4	5		10:00	1:00	9:25	9:28	10:05	10:57
5	7	Restorative #30 DO	10:00	0:30	9:31	9:33	9:59	10:47
6	55	Walk-in	10:00	0:30	9:54	9:54	10:12	10:45
7	57	Perio	11:00	1:00	10:45	10:48	11:03	11:47
8	58	Removable Pros	11:00	1:00	10:42	10:43	11:07	11:50
9	63	Bitesplint follow up	13:30	0:30	9:24	9:26	10:35	10:50
10	66	C + B	10:00	1:30	9:41	9:43	10:00	11:27
11	67		13:00	1:00	13:04	13:04	13:15	13:45
12	68	Follow up	13:00	1:00	12:50	12:51	12:58	13:15
13	70	Follow up	13:00	1:00	12:51	12:51	12:59	14:00
14	71	Walk-in	11:00	2:00	11:11	11:11	11:15	13:52
15	72	Follow up	13:30	1:00	13:41	13:42	13:50	14:25
16	73	DH/Cleaning & Exam	13:00	1:00	12:33	12:33	12:57	14:00
17	74	DH/Cleaning	11:00	1:00	10:23	10:25	11:10	11:40
18	75	Restorative	11:00	1:00	10:49	10:50	10:58	12:00
19	76	Extraction, 2 teeth	11:00	1:00	10:58	11:00	11:01	11:25
20	77	Consult	14:00	1:00	11:54	11:54	14:24	14:47
21	78	Consult, PreOp	13:00	0:30	12:18	12:21	13:30	14:00
22	79	Exam	10:00	1:00	10:17	10:19	10:20	11:00
23	82	Crown Delivery	12:30	0:30	12:13	12:17	12:33	13:12
24	83	Crown Delivery	14:00	1:00	13:49	13:50	14:02	15:46
25	84	Removable Pros	14:00	1:00	13:51	13:51	13:57	15:40
26	85	Follow up	13:00	0:30	11:50	12:00	12:59	13:06
27	1	Restorative	9:00	1:00	8:22	8:23	9:00	10:05
28	2	Recall prophy/fluoride varnish	9:00	1:00	8:27	8:27	9:25	10:05
29	3	Cleaning & Exam	9:00	1:00	8:32	8:32	9:04	9:55
30	5	Alginates, restore	9:00	1:00	8:45	8:45	9:05	9:55
31	7	Exam	9:00	1:00	9:01	9:02	9:05	10:10
32	8	Cleaning & fluoride	9:00	1:00	9:02	9:02	9:05	10:00
33	10	Cleaning, scaling, root planing, & fluoride	10:00	1:00	9:36	9:36	10:05	11:00
34	11	Restorative	10:00	1:00	9:41	9:41	10:00	11:00
35	12	Exam	10:00	1:00	9:43	9:43	9:54	11:00
36	14	Full-mouth debirdement, polish, fluoride varnish	11:00	1:00	10:35	10:35	11:25	12:25
37	43	Perio. Maint. Prophy - (Emergency) Changed, instead, limited ex w/Dr. Ofstehoge, Panorex, debirdement	10:00	1:00	10:00	10:00	10:14	11:15
38	44	Impressions and check teeth	10:00	0:30	10:00	10:00	10:05	10:45
39	46	Restorative	13:00	1:00	12:45	12:50	13:05	14:20
40	47	2 hrs. Scaling / Root-planing w/ anesthetic	13:00	2:00	12:25	12:27	13:05	14:55
41	51	Walk-in: Final C/Impression	13:00	1:00	12:57	12:57	13:14	14:10
42	52	Full-mouth debirdement, fluoride	14:00	1:00	13:15	13:15	13:45	15:00
43	54	Lower denture delivery	14:30	0:30	13:25	13:25	14:35	15:12
44	55	Restorative	14:00	0:30	13:50	13:50	14:00	14:45
45	55	Cleaning, Fluoride, Full mouth Debridement	14:00	1:00	13:45	14:45	15:05	15:45
46	56	flap + fillings	15:00	0:30	14:25	14:25	14:51	15:45
47	4	Follow-up on EXT	9:00	1:00	8:42	8:42	9:00	9:20
48	45	RCT	13:00	0:30	12:55	12:55	13:00	15:00
49	53	C + B	14:00	0:30	13:25	13:25	13:50	14:10

Day	Date	Number of appointments	Average Appointments
Mon	7-Jun	75	70
Tue	15-Jun	94	70
Wed	23-Jun	55	70
Thur	8-Jul	50	70
Fri	16-Jul	83	70
Mon	19-Jul	71	70
Tue	27-Jul	75	70
Wed	4-Aug	71	70
Thur	11-Aug	62	70
Fri	20-Aug	69	70

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